THE

Journal of the Society of Arts,

AND OF

THE INSTITUTIONS IN UNION.

111th Session.] FRIDAY, NOVEMBER 25, 1864. [No. 627. Vol. XIII.

TABLE OF CONTENTS.

Announcements by the Council.

Ordinary Meetings.

Wednesday Evenings at 8 o'clock.

Nov. 30.—"On the Mechanical Conditions of Railway Working to Prevent Destructive Wear and Risk." By W. Bridges Adams, Esq.

Dec. 7.—"On the Construction, Retardation, Safety, and Police of Railway Trains." By W. Bridges Adams, Esq.

Dec. 14.—"On Irish Industries; and the Irish International Exhibition of 1865." By Sir Robt. Kane.

Cantor Lectures.

There will be three Courses of "Cantor" Lectures on the following subjects during the ensuing Session:—

"On the Reproduction of Natural Forms by Art and Manufacture." By B. Waterhouse Hawkins, Esq., F.G.S., F.L.S.

"On the Application of Geology to the Arts and Manufactures." By Professor D. T. Ansted, M.A., F.R.S.

"On the Application of Chemistry to the Arts." By Dr. F. Crace Calvert, F.R.S.

The following is a syllabus of Mr. Hawkins's course, with the dates of delivery:—

Dec. 12th.—Lecture I.—Introductory:—On the nature and probable influence of museums of natural history and art collections, and their effect on the public mind and taste. (Illustrated.)

Dec. 19.—Lecture II.—Demonstrations of the unity of plan in the external forms of animals, the just appreciation of which facilitates the work of the artistic producer, and adds to the enjoyment of the intelligent possessor of works of art.

Jan. 16th, 1865.—Lecture III.—On the varieties of artistic treatment of the forms of animal and vegetable life—pictorial representation; conventional ornamental, allegorical, and symbolic combinations of animal forms.

Jan. 23rd.—Lecture IV.—On the fitness of designs, and their adaptation to the conditions of the materials in which they are to be produced. (Demonstrated by metal-work processes, sand-moulding, casting, and chasing).

Jan. 30th.—Lecture V.—On Ceramic Manufactures, with the Influence of the material on the design and its successful production—modern Terra Cotta, Della Robbia ware, Majolica, and Parian.

These Lectures are open to Members free of charge, and a Member has the privilege of introducing ONE Friend to each Lecture.

Proceedings of the Society.

Second Ordinary Meeting.

Wednesday, November 23rd, 1864; The Duke of Somerset, K.G., First Lord of the Admiralty, in the chair.

The following candidates were proposed for election as members of the Society:—

Barker, Charles Stuart, 12, Buckingham-street, Adelphi, W.C.
Durham, Makin, Thorne Hall, Thorne, Yorkshire.
Gale, William Joseph, 32, Torrington-square, W.C.
Hale, William, 6, John-street, Adelphi, W.C.
Kirchner, John, Peckham-common, S.
Partridge, William, 48, Newgate-street, E.C.
Pistrucci, Valerio, 28, Camden-street, N.W.
Pite, Frederick Robert, 38, Bloomsbury-square, W.C.
Pitman, E., 2, Ledbury-road, W.
Pittar, Arthur, 4, Kensington Park-gardens, W.
Rowlands, Percy Jones, 24, Notting-hill-terrace, W.; and India Office, Westminster, S.W.
Slater, Robert, 104, Fore-street, E.C.
Smith, William Binns, 7, New-square, W.C.
Thompson, F., South Parade, Wakefield.
Tichborne, Sir Alfred, Bart., Tichborne-park, Hants, and 13, James's-street, Buckingham-gate, S.W.
Todd, William, 24, Wellington-road, St. John's-wood, N.W.
Tozer, Thomas, 55, Dean-street, Soho, W.
Van de Weyer, M. Sylvain (Belgian Minister), 3, Grosvenor-square, W.
Venning, Walter C., 9, Tokenhouse-yard, E.C.

Verschoyle, Colonel H., 23, Chapel-street, Belgrave-square, S.W.
Wilson, George, Cyclops Steel and Iron Works, Sheffield.
Wingate, James Forman, Club-chambers, 15, Regent-street, S.W.

The Paper read was—

ON THE APPLICATION OF IRON TO THE PURPOSES OF NAVAL CONSTRUCTION.

By Wm. Fairbairn, Esq., LL.D., F.R.S.

From the earliest period of history to the present high state of civilisation, we behold a long and interesting succession of improvements in the construction of weapons of war. Man in his savage state contrived instruments of aggression as well as defence. Tomahawks, spears, and arrows composed of wood, shod with stone or bone, were adopted. As he advanced in civilisation, and became acquainted with minerals, he had recourse to a rude description of manufacture by reducing the ores and extending their uses to the purposes of peace as well as to the art of war. In fact, he found that the application of heat to the iron ores produced a semifluid or ductile mass, that could be drawn or consolidated, under a series of blows, into the required forms calculated to supply his wants. It was in this way that the early workers in iron—the Tubal Cains of former days—produced weapons for attack and defence. No doubt they would soon find—once the discovery was made—that iron, at different degrees of temperature, and under different conditions of time and the heat to which it was exposed, would assume the different forms of rigidity, ductility, &c.; and, without any knowledge of combined carbon, oxygen, &c., as known in modern times, they actually found, at a later period, that a certain process, under these conditions, produced steel, from whence the famous weapons known as the "Blades of Damascus" were made.

From these early stages of manufacture to the middle of the last century, we have little to boast of in the production of iron and steel. Something was certainly done during this long interval, but we have no traces of any important improvement until 1784, when Cort first introduced his invention of the puddling furnace and the rolling of plates and bar iron. Hammered iron plates were occasionally made, but seldom used unless for special purposes; and it was not until the introduction of rolls that anything in the shape of rolled plates could be obtained. At that time, and for several years subsequently, little or nothing was done to encourage the manufacture, but the new process of rolling simplified the operation and gave greatly increased facilities for the manufacture of this important article of commerce. Rolled plates were first employed in the construction of boilers; and those of the haystack form were made as early as 1786, and were chiefly employed for raising steam for the atmospheric pumping engines of Cornwall, and those for the collieries of Northumberland and Durham. More recently, or about the same date, Mr. Watt introduced the waggon-shaped boiler for his reciprocating sun and planet-wheel engine, but we have no traces of iron boats or ships at a date antecedent to that of Cort and Watt.

At the commencement of the present century it is more than probable that the first construction of iron canal boats took place; and we have evidence of their existence in Staffordshire about the year 1812 or 1813. From that time to the present iron boats have been successfully employed on canals.

From 1812 to 1822, to use a more familiar expression, there was an interregnum of progress for a period of ten years, and we hear nothing of iron as a material for ship-building, till the Horsely Company built the *Aaron Manby*, which was sent to London in sections, reconstructed in one of the docks, and navigated to Havre and Paris by the late Admiral Napier.

It was supposed that the success of the *Aaron Manby* would have stimulated exertions in the same direction, but important discoveries, like other things of great magnitude, require time to bring them to maturity, and another period of rest ensued, from 1822 to 1829, when a new discovery was made by Mr. Houston, of Johnstone, near Paisley, in which it was found that a light boat, with two horses, had sufficient power to convey passengers on a canal at the rate of nine to ten miles an hour. This discovery was made at a time when a new and important era in the history of transit on railways burst unexpectedly upon the public in the experimental tests and competitive trials of locomotive engines at Rainhill. The results of these trials created alarm in the minds of all the canal proprietors of the kingdom. They became anxious about their property; and the speed of ten miles an hour, as attained by Mr. Houston in his gig-boat, was the only gleam of hope left to enable them to meet, with anything like success, the alarming and powerful competition of the rail and locomotive.

Things were in this state when the governor and council of the Forth and Clyde Canal employed the writer to institute a series of experiments to determine the law of traction, and account for the phenomena of the absence of surge at high velocities on canals. These experiments were conclusive and interesting, and the report was published shortly afterwards, at the request of the governor and council of the Forth and Clyde Canal Company. In this report will be found a detailed account of the experiments and the conclusions and recommendations arrived at, the most prominent of which were the introduction of iron vessels and steam on the locomotive principle as a substitute for horses. Acting upon this recommendation four steam vessels were constructed at Manchester, one a twin-boat, with the paddle-wheel in the centre, and a second, the *Lord Dundas*, with the paddles recessed into the dead wood of the stern. The first was an experimental boat, but the second plied for several years as a passage boat between Port Dundas and Lock 16.

Simultaneous with these vessels another and a larger iron vessel, 84 feet long and 14 feet beam, with recessed paddles in the stern, was also built at Manchester in 1831, and navigated through the locks of the Mersey and Irwell to Liverpool, and from thence to Greenock. This was the second iron vessel that put to sea, if we except the *Lord Dundas* light boat, which performed the same voyage from Liverpool to Glasgow in the previous year. The name of this vessel was the *Manchester*, and for many years it was employed as a coasting vessel, carrying goods and passengers between Port Dundas, Grangemouth, and Dundee.

During the time of these constructions Messrs. John and MacGregor Laird were engaged in similar undertakings for the Irish canals, and were present at most of the experimental trials of light boats on the Irwell. These boats were built at Birkenhead, and forwarded in sections to Ireland. About the same time, or shortly after the Manchester canal boats were introduced on the Forth and Clyde Canal, Messrs. Laird built the *Alburka*, a small iron vessel, that went out to Africa with the Landers and Mr. Mac Gregor Laird, for the exploration of the Niger. The whole of these vessels were confirmatory of the great superiority of iron over wood as a material for ship-building; and we have only to refer to the extensive use and enormous increase that have taken place in its application, not only in this country, but in every maritime state of the globe, to be convinced of the soundness of the principles and the great superiority of the iron ship.

Having briefly noticed the origin and subsequent improvements that have taken place in iron ship-building, it is important that the naval architect should have all the information that can be obtained, and for this purpose we have on this very important question to direct attention to the following divisions of the subject:—

1st. The strength of plates when torn asunder by a direct tensile strain in the direction of the fibre, and when torn asunder across it.

2nd. On the strength of the joints of plates when united by rivets as compared with the plates themselves.

3rd. On the resistance of plates in varied forms of construction to the force of compression.

And lastly. On the distribution, strength, and value of wrought-iron plates and frames as applied to ships and other vessels.

On the first of these, where the iron plates were torn asunder in the direction of the fibre and across it, the following results were obtained:—

TABLE I.

DESCRIPTION OF PLATES.	Mean breaking weight in the direction of the fibre in tons per square inch.	Mean breaking weight across the fibre in tons per square inch.
Yorkshire Plates	25·770	27·490
Yorkshire Plates	22·760	26·037
Derbyshire Plates	21·680	18·650
Shropshire Plates	22·826	22·000
Staffordshire Plates	19·563	21·010
Mean.........	22·519	23·037

From the above it will be observed that the average strength of plates is about 22½ tons to the square inch, the maximum being in favour of the Yorkshire plates, and the minimum those of Staffordshire.

It would probably be unfair to class plates with bar iron of the same quality, as bar iron is much more elongated and drawn into fibre in passing through the rolls than the same material when drawn into plates; we may, however, compare plates with bars experimented upon by the late Mr. Telford, who found, in his experiments to determine the strength of different irons previous to his construction of the Menai Suspension Bridge, that out of nine fagoted specimens, selected from the Swedish, Welsh, and Staffordshire irons, he obtained a tenacity of 29·25 tons per square inch.

	Tons.	
Captain Brown's experiments for the same purpose gave.........	25·00	per sq. inch.
Minord and Desames'	25·00	,,
Yorkshire plate experiments ...	24·50	,,
Shropshire plates	22·82	,,
Derbyshire plates	21·68	,,
Staffordshire plates	20·32	,,
Giving a mean tenacity for plates of	23·22	tons per sq. in.

Comparing this with the strength of bar iron from the best material, and making allowance for the latter having been worked, rolled, and drawn into fibre to a greater extent than plates, the difference in strength is not so great as might have been expected, being in the ratio of 29 : 23 or 1 : ·8 nearly.

Plates of ordinary manufacture, or such as are used in ship-building, seldom exceed 20 tons to the square inch. Unfortunately, many of these are considerably under that mark, but on no account should any plate be allowed to enter into the construction of a sea-going vessel under a tensile strain of from 20 to 22 tons per square inch. Small vessels, such as boats for canals and rivers, may venture upon an inferior standard of quality, but even with this allowance there is no economy in the use of bad material, which is neither safe nor durable.

DUCTILITY, ELONGATION, &c.—We have already noticed that ductility is a property highly valuable in iron, and, we may add, when combined with tenacity it becomes more so; in fact, ductility is the true measure of strength and of its practical utility. These properties being of great importance in the manufacture of iron, it may be useful to give a few examples, derived from recent experiments, illustrating the principle on which it is supposed that good iron yields and becomes attenuated when acted upon by forces which draw it in the direction of the fibre.

It has been stated that iron, like most other metals, is of a ductile character. In this respect, however, it is inferior to gold, silver, and platinum, but it is in advance of copper, zinc, and tin, and may be considered superior to any of these metals on account of its tenacity, and from this we derive its adaptation to the art of construction and its value as an article of commerce. Iron is, therefore, of inestimable value, and, combining properties such as those enumerated, it becomes one of the most important and useful of metals.

The following experimental results were derived from seven different thicknesses of iron plate. They were obtained from four different firms, and marked A, B, C, and D, as under:—

A. Six specimens of iron plates.
B. Seven specimens.
C. Seven specimens, homogeneous metal.
D. Seven specimens, rolled iron.

The whole of these specimens were torn asunder by a tensile strain, and recorded in the following summary:—

TABLE II.

Summary, giving mean Tensile Strength of each Series of Plates, or Statical Breaking Strain.

Approximate thickness of the Plates in inches.	TENSILE BREAKING WEIGHT PER SQUARE INCH OF SECTION.				Mean of Plates of the same thickness in tons.
	A Plates.	B Plates.	C Plates.	D Plates.	
inch.	tons.	tons.	tons.	tons.	tons.
¼	24·344	24·167	30·703	17·470	24·171
½	25·750	23·220	33·694	11·055	23·430
¾	...	29·432	30·913	26·473	...
1½	24·158	22·299	26·197	25·158	24·453
2	25·348	23·657	27·038	24·634	25·169
2½	24·110	23·921	27·506	22·732	24·569
3	25·039	23·540	27·386	24·159	25·031
Mean of thin plates	25·047	25·606	31·770	18·333	...
Mean of thick plates	24·644	23·354	27·032	24·171	...
Mean of all of one make ...	24·792	24·319	29·063	21·669	..

The order of merit in the thinner plates is, (1) C; (2) B; (3) A; (4) D. With thicker plates it is—(1) C; (2) A; (3) D; (4) B. The mean of the whole gives (1) C; (2) A; (3) B; (4) D.

The homogeneous metal plates exhibit throughout the highest tenacity, but the tenacity decreases as the plates are made thicker. Of the iron plates, those marked A are most uniform in strength, the extreme difference being 1·64 tons. The B plates vary to the extent of 7·133 tons, and the D plates 14·103 tons, but the quarter and half-inch plates of the latter series would appear to have been burnt or injured in the manufacture.

Taking the means given in the last column, we see that in the average there is no great difference between the thicker and thinner plates. The extreme variation in these means is 1·74 tons. If we compare these means with the corresponding mean densities, there is an evident correspondence, thus—

	Density.		Tenacity.
1½ inch plates......	7·7471	...	24·453
2-inch plates	7·7684	...	25·169
2½-inch plates......	7·7660	...	24·569
3-inch plates	7·7666	...	25·031

Here the density and tenacity increase and diminish together. The same correspondence will be found, gene-

rally speaking, in each individual case on comparing the two tables, but there are exceptions in the case of the D plates. Taking into account the fact that the specimen employed in obtaining the specific gravity was cut at a distance of about 10 inches from the part broken by tension, the coincidence is sufficiently striking. The comparison holds good if we take the means of plates of the same manufacture, with one exception—

	Density.		Tenacity.
A plates	7·8083	...	24·644
B plates	7·7035	...	23·354
C plates	7·9042	...	27·032
D plates	7·6322	...	24·171

TABLE III.

Summary, giving the ultimate elongation per unit of length.

Approximate thickness of the plates in inches.	ULTIMATE ELONGATION PER UNIT OF LENGTH.				Mean of Plates of the same thickness in tons.
	A Plates.	B Plates.	C Plates.	D Plates.	
Inch.					
¼	·0620	·0300	·2560	·0080	0·0890
½	·0760	·0400	·1000	·0111	0·0568
¾	..	·1000	·2080	·0400	0·1160
1½	·1763	·1462	·1925	·1925	0·1769
2	·3050	·2525	·3450	·1788	0·2703
2½	·2880	·3200	·2950	·1600	0·2658
3	·3200	·2650	·2575	·2333	0·2689
Mean of thinner plates ...	·0690	·0566	·1880	·0197	...
Mean of thicker plates	·2723	·2459	·2725	·1913	...
Mean of all the plates	·2046	·1650	·2363	·1176	...

In this table the order in which the different series of plates stand with reference to ultimate elongation nearly coincides with the order in which they stand in reference to tenacity if the means of plates of the same manufacture are compared; but, on the other hand, if we compare the means of plates of the same thickness, we find that on the whole the ultimate elongation increases as the plates become thicker, whilst no law of this kind could be perceived in the mean tenacities.

Mr. Mallet has introduced a new co-efficient of strength of considerable importance in these inquiries, namely, the dynamic resistance to rupture, or foot pounds of work done in rupturing the material. This may be estimated with sufficient accuracy by multiplying the breaking weight in lbs. by half the ultimate elongation, and from thence we derive the following results:—

TABLE IV.

Mr. Mallet's Co-efficient or work done in causing rupture, corresponding with resistance to impact.

Approximate thickness of the plates in inches.	FOOT POUNDS OF WORK CAUSING RUPTURE.				Mean of Plates of the same thickness.
	A Plates.	B Plates.	C Plates.	D Plates.	
inch.					
¼	1690·5	812·0	8802·7	156·5	2865·4
½	2191·8	1040·2	3773·7	137·4	1785·8
¾	...	3296·5	7201·5	1186·0	3895·0
1½	4767·5	3651·3	5648·0	5424·0	4872·7
2	8659·0	6690·2	10448·0	4933·1	7682·6
2½	7776·8	8573·4	9087·2	4073·7	7377·7
3	8973·7	6987·0	7878·0	6312·7	7787·8
Mean of thinner plates ...	1941·1	1716·2	6592·6	493·3	...
Mean of thicker plates	7544·2	6475·5	8265·3	5185·9	...
Mean of plates of same make	5676·6	4435·8	8806·5	3174·8	...

It will be noticed that the numbers given in the case of the thinner plates are very variable, in consequence of the great fluctuations in the value of the ultimate elongation in those plates. This irregularity would have been eliminated if several specimens of each had been tried, or, still better, if the specimens had been so long that the elongation of a much greater extent of metal could have been ascertained. The results obtained in the thicker plates, with precisely similar round bars, are more uniform.

Bearing this in mind, the table exhibits several remarkable results. First, taking the means of plates of the same thickness, it appears that the dynamic resistance increases progressively as the plates increase in thickness; in fact, the thick plates exhibit 2½ times the resistance of the thinner ones. The only exception to this general law is the quarter-inch homogeneous metal plate, which was extremely ductile.

Then, in the next place, it is to be observed, that the dynamic resistance increases with the thickness of the plates in a higher ratio in the iron plates than in the homogeneous metal plates, thus:—

DESCRIPTION OF PLATES.		Thinner Plates. Foot Pounds.	Thicker Plates. Foot Pounds.	Ratio.
A Plates	Iron.	1941·1	7544·2	1 to 3·82
B Plates	Iron.	1716·2	6475·5	1 to 3·77
D Plates	Iron.	493·3	5185·9	1 to 10·52
C Plates	Steel.	6592·6	8265·3	1 to 1·25

The result of this is that the superiority of the homogeneous metal to iron is very striking in the thin plates, but becomes less and less as the plates increase in thickness. Thus, taking the best of the iron plates, namely, series A, for comparison, we have the following ratios between the iron and steel:—

THICKNESS IN INCHES.	A. Plates	C. Plates	Ratio of Dynamic resistance.
	Foot-pounds.	Foot-pounds.	
¼-inch	1690·5	8202·7	1 to 5·21
½-inch	2191·8	3773·7	1 to 1·72
¾-inch		7201·5	
1½ inches	4767·5	5648·0	1 to 1·19
2 inches	8659·0	10448·0	1 to 1·20
2½ inches	7776·8	9087·2	1 to 1·17
3 inches	8973·7	7878·0	1 to 0·88

In this table we see that the ratio decreases progressively with great regularity from 1 : 5·21 to 1 : 0·88; that is, the work done in rupture is with ¼-inch plates five times as great with homogeneous metal as with iron, but the superiority decreases, and with 3-inch plates the resistance of the iron is 12 per cent. greater than that of the homogeneous metal. This result precisely corresponds with the results obtained in the trials with ordnance.* Thus, if we take the mean between the thinnest plate which resisted the shot of any given weight, and the thickest which was penetrated by it, as the maximum thickness of penetration with that projectile, we have from the experiments at Shoeburyness the following results:—

RIFLED GUN.	Weight of Projectile in lbs.	Least thickness which would resist the shot in inches.		Ratio of resistance of plates of equal thickness.
		A Plates.	C Plates.	
Wall piece	0.344	0·87	1·62	1 : 1·97
Armstrong	6·25	1·25	1·15	1 : 1·18
,,	11·56	1·75	1·75	1 : 1·00
,,	24·81	2·25	2·50	1 : 0·81

* See Mr. Fairbairn's Experimental Researches, 1st Report of the Special Committee on Iron.

The results in this table are only roughly approximate; but they show a decreasing resistance in the C plates when compared with the A plates. The results in the last column strikingly correspond with those in the preceding table, if plates of the same thickness be compared. On comparing table 4, giving Mallet's coefficient, with the specific gravities, similar correspondence is, observable to that already noticed in the case of tensile breaking strain. The exceptions also occur in the same series, namely, the D plates. Of the iron plates of different manufacturers, the A series throughout manifest the greatest amount of dynamic resistance. Next to it the hammered plates of series B, and, lastly, the rolled plates of series D. Taking the thicker plates, which give the most accurate results, and employing the iron plates of series A as a standard of comparison, we have the following ratio of dynamic resistance:—

A Plates........................	1000
B Plates........................	858
C Plates........................	1095
D Plates........................	688

The maximum difference amounting to 41 per cent. between C and D, and 31 per cent. between A and D.

To the above extract from the Report of the Special Committee on Iron, we may add the results of some experiments on the tensile strength of S C ♕ bars, conducted some years since at Woolwich, by Mr. Loyd, Inspector of Machinery. To that gentleman we are indebted for the following results:—

TABLE V.

Summary of Results, Tensile Strength of Bars.

Length of Bar in inches.	Diameter of Bar in inches.	Breaking Weight in Tons.	Elongation in inches.	Elongation per unit of length.
120	1·375	32·210	26·0	·216
42	1·375	32·125	9·8	·233
36	1·375	32·350	8·8	·244
24	1·375	32·000	6·2	·258
10	1·375	32·290	4·2	·420

In another series of experiments it was found that the continued strain of three-fourths of the breaking weight had no effect upon the bars, and that it might have been prolonged indefinitely without injury to the cohesive force by which the particles were united. These facts, although exceedingly interesting at the time, have since been carefully investigated, and, having to refer to them in the sequel, it will be sufficient for our present purpose simply to advert to the plastic nature of the iron by which the bars sustained an amount of elongation exceeding that of most other irons.

It appears from Table V. that the rate of elongation of wrought iron bars increases with the decrease of their length; thus, while a bar of 120 inches has an elongation of ·216 inch per unit of length, a bar of ten inches has an elongation of ·420 inch per unit of its length, or nearly double what it is in the former case. The relation between the length of a bar and its maximum elongation per unit of length, may be appropriately expressed by the following formula, viz.:—

$$l = \cdot 18 + \frac{2\cdot 5}{L}$$

where L represents the length of the bar, and l the elongation per unit of length of the bar. These results are of some value, as they exhibit the ductility of wrought iron at a low temperature, and also the greatly increased strength which it exhibits with a reduced section under strain.

2ND. ON THE STRENGTH OF THE JOINTS OF PLATES WHEN UNITED WITH RIVETS, AS COMPARED WITH THE STRENGTH OF THE PLATES THEMSELVES.—To ascertain the facts and to show how nature works in this direction, we are compelled to have recourse to the old but certain test of experiment. This appeared to me as the only certain method of arriving at truth in physical research. Resorting, therefore, to this expedient it will be necessary to note, what appears obvious to the most casual observer acquainted with mechanical constructions, that to unite plates together so as to make the joints as secure as if they were continuous and homogeneous in character is a desideratum. It would be desirable, for example, to have the longitudinal sheathing of our ships in strips or plates without joints; but this could not be done by welding, and here we have to resort to the expedient of uniting them together by bolts or rivets. Now it has been found that the latter process is by far the strongest and most endurable, as the rivets are generally put in hot and are hammered, or, what is decidedly preferable, compressed by the riveting machine into the holes prepared for their reception. A good rivet requires a head on each side, the same as a bolt and nut, but there is this difference, that the rivet becomes, when carefully inserted, part and parcel of the plate, and, when duly proportioned as to size and number, is equal in strength to the plate itself, minus the part punched out by the rivets. It is therefore desirable in every case where plates have to be joined that they should be united by rivets.

In ship-building, and in every other construction where wrought-iron plates form the principal material, it is essential that this part of the inquiry should be explicitly and clearly understood. It is therefore most desirable that the question should be thoroughly investigated, and that all those engaged in constructions of this kind should be fully aware of their importance, not only as regards the acquisition of knowledge, but the heavy responsibilities which attach to works on which the lives and property of the nation and of individuals depend. Impressed with these views, I may venture to submit to the engineer and naval architect the results of experiments which from time to time, and for a long series of years, have engaged my attention. In attempting to unite plates by the insertion of rivets we have to consider:—

1st. PUNCHING.—Now this is a very important part of the shipbuilding process, first, that the holes should be clean and well cut, and that by a perfectly flat steel punch; secondly, the holes in the plates when put together, should be coincident, and have a common centre, and should cover each other. To accomplish this, it is desirable that the punching should be done, if possible, by a self-regulating machine, but when this cannot be accomplished, the greatest care should be observed on the part of the workman to see that the punching is executed so as to bring the holes to coincide, and not incur the anomalous condition of having them half blind—as it is technically called—or nearly blind altogether—a circumstance which in rough imperfect work too often occurs.

It is much to be regretted that more attention is not paid to these operations, as inaccurate punching is seriously detrimental to the plates; and there is nothing which causes more injury to the security and tightness of the joints than bad riveting. The remedy chiefly in use by workmen as a compensation for the want of coincidence, is to drive through both holes a tapered steel pin, or drift, forcing and tearing the plate in every direction; and in order that they should obey the dictates of physical force as administered by a sledge hammer, in the hands of one whose muscular developments are greatly in excess of the reflective functions of his brain, the holes are enlarged, and the rivet very imperfectly closed, at an oblique angle to the face of the plate. This is a process which cannot be too much condemned, and appears to be the strongest argument against the punch. Some engineers, to avoid this evil, insist on having the holes in the plates drilled, but, according to our judgment, this system is better adapted to bolts than rivets, as the

drill makes a perfectly parallel hole, which is never so sound nor yet so secure as that which comes from the punch; and for this reason, that in punching a hole through an iron plate, it is not exactly cylindrical, parallel, or smooth, but the frustrum of a cone, and hence follows the superiority of the joint, as more closely incorporated with the plates. It will not be necessary in this place to determine the law by which this particular form is attained, suffice it to observe that the diameter of the punch is to the hole in the die as 1 : 1·15 or 1 : 1·20 for ordinary work, and we have therefore a hole in the plate or the piece punched out with oblique sides, the angles of which vary in the ratio of the thickness of the plates, and these with coincident holes form a sound and perfect rivet. Now this form of hole is not injurious but of great value as regards the strength of the joints, as the conical form of the holes is equivalent to a countersunk rivet on each side. It is moreover highly advantageous in ship-building, where the rivets are countersunk on one side, and where a perfectly smooth surface is required for the passage of the currents on the other.

To arrive at the strongest form of joint, it is necessary in this case to punch the plates so that the narrow sides of the holes are in contact. This is the more essential, as the heads of the rivets are easier formed, and the holes better filled, when performed either by the hammer or by compression. By the latter process—machine riveting—the joints are brought closer together by contraction as the rivet cools, and the adhesion of the two surfaces is greatly augmented.

Riveting.—During the early stages of iron construction, and as recent as the time to which we have alluded when iron shipbuilding was first introduced, there was only one system of uniting the joints of iron plates, namely, the overlap single-riveted joint. Now it is widely different, as the variety of purposes to which plates are applied renders a new and entirely different principle of riveting essential. When the double-riveted joint came into use is uncertain, but its advantages were first shown during the progress of my earlier experiments. These experiments were conclusive as to the value of the double riveted joint, but a new system of iron construction has been developed in the experimental researches which led to the form and construction of the Britannia and the Conway tubular bridges. In these structures it was imperative that the joints submitted to tension should be equal, or at least approximate closely to the strength of the solid plate; and after a great number of experiments it was found that the old system of single and double joint riveting was not only inapplicable but weak and insecure. This insecurity led to a more extended series of experiments, a summary of results of which I have now to record for the benefit of those who are not acquainted with the facts, and to whom it may be useful in the varied forms of construction as applied to iron ships and bridges.

General Summary of Results as obtained from Experiment.

No. of Experiments.	Cohesive strength of the plates. Breaking weight in lbs. per square inch.	Strength of double-riveted joints of equal section to the plates, taken through the line of rivets. Breaking weight in lbs. per square inch.	Strength of single-riveted joints of equal section to the plates, taken through the line of rivets. Breaking weight in lbs. per square inch.
1	57,724	52,352	45,743
2	61,579	48,821	36,606
3	58,322	58,286	43,141
4	50,983	54,594	43,515
5	51,130	53,879	40,249
6	49,281	53,879	44,715
7	43,805	...	37,161
8	47,062	...	...
Mean.	52,486	53,635	41,590

The relative strengths will therefore be—

For the plate 1,000
Double-riveted joint 1,021
Single riveted joint 791

From the above it will be seen that the single-riveted joints have lost one-fifth of the actual strength of the plates, whilst the double-riveted have retained their resisting powers unimpaired. These are important and convincing proofs of the superior value of the double joint; and in all cases where strength is required this description of joint should never be omitted. It appears when plates are riveted in this manner, that the strength of the joints is to the strength of the plates of equal sections of metal as the numbers,—

	Plate.		Double-riveted joint.		Single-riveted joint.
	1,000	:	1021	and	791
In a former analysis it was	1,000	:	933	and	731
Which gives us a mean of	1,000	:	977	and	761

which in practice we may safely assume as the correct value of each. Exclusive of this difference, we must however deduct 30 per cent. for the loss of metal punched out for the reception of the rivets; and the absolute strength of the plates will then be to that of the riveted joints as the numbers 100, 68, and 46. In some cases, where the rivets are wider apart, the loss sustained is however not so great; but in boilers and similar vessels, where the rivets require to be close to each other, the edges of the plates are weakened to that extent. In this estimate we must however take into consideration the circumstances under which the results were obtained, as only two or three rivets came within the reach of experiment; and, again, looking at the increase of strength which might be gained by having a greater number of rivets in combination, and the adhesion of the two surfaces in contact, which in the compressed rivets by machine is considerable, we may fairly assume the following relative strengths as the value of plates with their riveted joints:—

Taking the strength of the plate at 100
The strength of the double riveted joint will be 70
And the strength of the single riveted 56

These proportions may therefore in practice be safely taken as the standard value of joints such as are used in vessels where they are required to be steam or water tight, and subjected to pressure varying from 10 to 100lbs. on the square inch.

Rivets.—On this subject we have to consider the diameter, pitch, and length necessary to be observed in forming sound and tight joints without injury to the plates beyond the amount of metal punched out for the reception of the rivets. I have investigated this subject with great care, and, from my own personal knowledge and that of others, have collected a number of practical facts, such as long experience alone could furnish. From these data I have been enabled to compute the following table, which for practical use I have found highly valuable in proportioning the distances and strength of rivets in joints requiring to be steam or water-tight.

Table exhibiting the Strongest Forms and best proportions of Riveted Joints, as deduced from the Experiments and Actual Practice.

Thickness of plates in inches.	Diameter of rivets in inches.	Length of rivets in inches.	Distance of rivets from centre to centre in inches.	Quantity of lap in single joints in inches.	Quantity of lap in double joints in inches.
·19 = $\frac{3}{16}$	·38 }	·88 }	1·25 } 6	1·25 }	For the double riveted joint add 2-3rds of the depth of the single lap.
·25 = $\frac{4}{16}$	·50 } 2	1·13 }	1·50 }	1·50 } 6	
·31 = $\frac{5}{16}$	·63 }	1·38 }	1·63 } 5	1·88 }	
·38 = $\frac{6}{16}$	·75 }	1·63 } 4·5	1·75 }	2·00—5·5	
·50 = $\frac{8}{16}$	·81 }	2·25 }	2·00 }	2·25 }	
·63 = $\frac{10}{16}$	·94 } 1·5	2·75 }	2·50 } 4	2·75 } 4·5	
·75 = $\frac{12}{16}$	1·13 }	3·25 }	3·00 }	3·25 }	

The figures 2, 1·5, 4·5, 6, 5, &c., in the preceding table are multipliers for the diameter, length, and distance of rivets, also for the quantity of lap allowed for the single and double joints. These multipliers may be considered as proportionals of the thicknesses of the plates to the diameter, length, distance of rivets, &c. For example, suppose we take three-eighths plates, and required the proportionate parts of the strongest form of joint, it will be—

$$\cdot 375 \times 2 = \cdot 750 \text{ diameter of rivet, } \tfrac{3}{4}\text{-inch.}$$
$$\cdot 375 \times 4\tfrac{1}{2} = 1\cdot 688 \text{ length of rivet, } 1\tfrac{3}{4} \text{ inches.}$$
$$\cdot 375 \times 5 = 1\cdot 875 \text{ distance between rivets, } 1\tfrac{7}{8} \text{ inches.}$$
$$\cdot 375 \times 5\tfrac{1}{2} = 2\cdot 063 \text{ quantity of lap, single riveted joint, 2 inches.}$$
$$\cdot 375 \times 5\tfrac{1}{2} + \tfrac{2}{3} = 3\cdot 438 \text{ quantity of lap, double riveted joints, } 3\tfrac{1}{2} \text{ inches.}$$

·75, 1·68, 1·87, 2·06, and 3·43 are therefore the proportionate quantities necessary to form the strongest steam or water-tight joints on plates three-eighths of an inch thick.

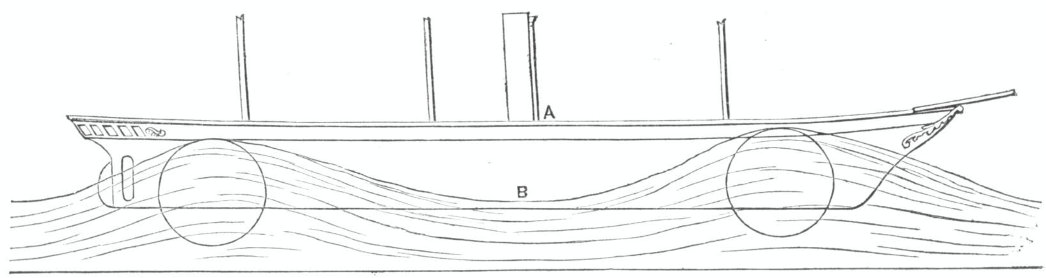
3rd. ON THE RESISTANCE OF PLATES, AS APPLIED IN DIFFERENT FORMS TO THE FORCE OF COMPRESSION.—We have already noticed, when treating of the tensile strain to which a ship is subjected, that another equally important force is in operation in the movements of the vessel—that of crushing or compression. This is more apparent in iron than in wooden structures, as thin plates are liable to distortion when forcibly compressed in the direction of their lengths; and in ship-building, as in tubular girder bridges, this tendency to "pucker" requires to be carefully guarded against. When conducting the experiments for the Conway and Britannia Bridges, this weakness was strikingly apparent, and was carefully considered; and as the strains in that of a ship and a monster tubular girder are analogous, it is necessary in both structures that the resistances should be clearly understood, the two forces nicely balanced, and the tendency to buckle prevented.

To enable the practical ship-builder to acquire this knowledge, and become acquainted with the laws which govern iron structures of different forms, it will be necessary to investigate this question attentively, and endeavour to establish sound principles of construction in the minds of those who are entrusted with designs of such great public importance.

To construct a perfectly secure iron ship, every one of the transverse joints should be planed, in order that the ends of the plates may butt and form a solid joint. This connection is the more important, as the action of a vessel pitching at sea is a continued series of alternate strains of tension and compression. This motion is the most violent to which a vessel afloat is subject, and it is the most injurious to the structure. A vessel of war covered with armour plate, or a mercantile ship with a heavy cargo, plunges heavily at sea, and the waves meet her with violent shocks, so much so as to slacken her speed, and cause her to tremble or vibrate on the crest of the wave. This motion is somewhat analogous to that of rolling, but much more severe, as that part of the vessel which is left unsupported acts as a weighted lever on a transverse axis through the ship's centre of gravity, and thus produces severe strains at midships. By extending the weights or cargo in the direction of the bows and stern these strains are increased, and this, as a general rule, should be avoided by concentrating the cargo as much as possible at the centre of the ship.

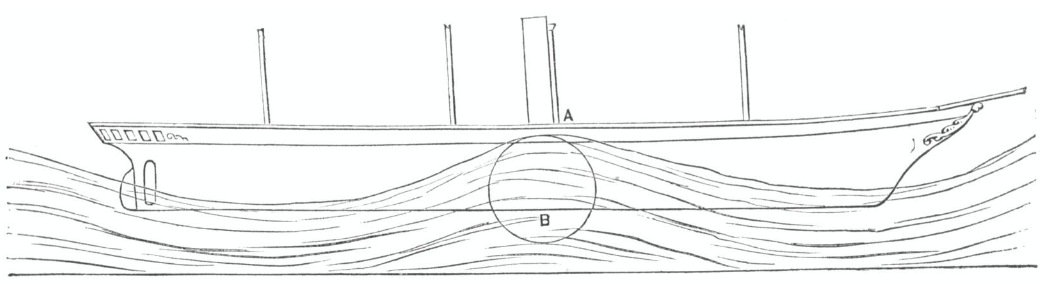
Let us suppose a vessel in the middle of the Atlantic or Pacific Ocean having to encounter a rolling sea in a storm, where the elevation from the trough to the crest of the wave is 24 feet, and the distance from point to point 380 to 400 feet; and, supposing that these waves move at a velocity of 10 knots an hour, and we have a vessel, as represented in fig. 1, with two waves, one at the bow and another at the stern, and her midships

FIG. 1.



partially unsupported, as if two liquid rollers (if I may be allowed the expression) were passing at the above rate under her bottom. In this position the strains would have a tendency to crush the material composing the upper deck at A, and to tear asunder the hull or bottom B. Hence the necessity for increased resistance in those parts. Reversing this position, and supposing that the liquid rollers or waves have passed from the bows and stern to the centre of the ship, and we have her balanced in the shape of a scale-beam as at fig. 2, with both ends only

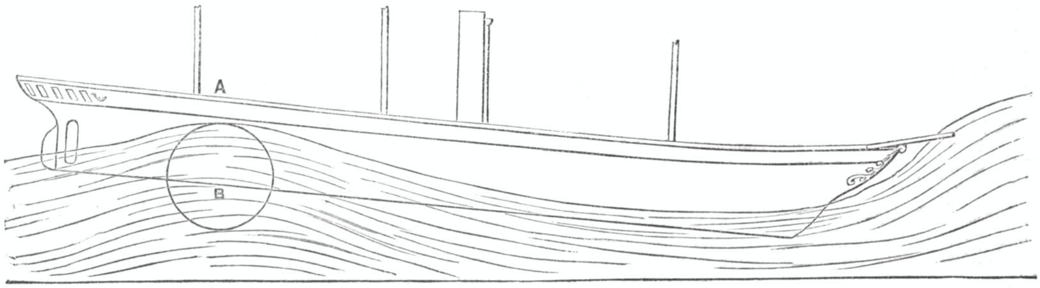
FIG. 2.



partially supported. In this position the strains are reversed, and we have the crushing force along the bottom as at B, and the tension or tearing force pulling at A on the upper deck.

Assuming, again, that the wave has passed from the centre of the vessel half-way to the stern, and we have the same forces continued, namely, the maximum of tension on the upper deck at the point A immediately over the apex of the surge, and compression at B below (fig. 3).

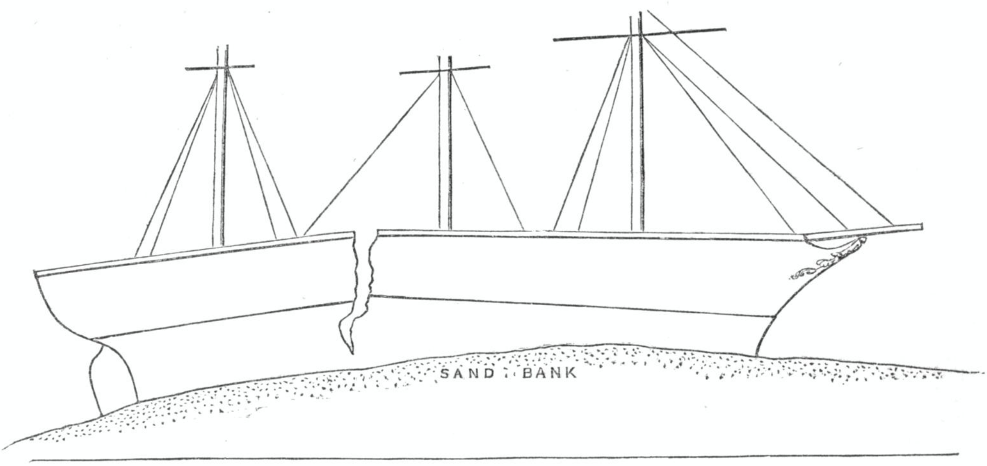
Fig. 3.



In these forms we have nearly all the disturbances and variety of strains, independent of rolling and wrenching, to which vessels are subjected when afloat. Under other circumstances, such as a vessel stranded on a lee-shore, beaten on rocks or sandbanks, similar forces of much greater intensity come into operation, and the only safeguard in these conditions is increased strength at midships and a sufficient number of water-tight bulk-heads, dividing the ship into five or six different compartments.

From the above it will be seen that alternate strains of varying intensity are continually in action during the time the vessel is plunging at sea with the whole of her cargo on board.

On the question of the strength of iron ships, we could not have a more striking illustration of the disastrous effect of defective construction, than that which took place in the case of the Montreal Ocean Mail steamer *Jura*, only a fortnight ago, which, by some mistake of the pilot, ran upon the Crosby-spit, a narrow sandbank, at the entrance of the Mersey. She was running full speed at the time. The fore part of her keel became fixed on the bank, the stern hanging in deep water, and the result was she parted at midships, as shown in the sketch, entirely for want of a judicious application of iron stringers on each side of the upper deck, calculated to balance the area of the hull at midships, and to resist the force of tension which tore her assunder on the upper deck.



On this very important inquiry of alternate strains, we are fortunate in having before us a series of experiments on the endurance of iron-jointed beams subjected to these changes. Not exactly similar to that of a steam engine beam, but a less severe test, arising from alternately reimposing and removing the load. This, it will be observed, was simply a constant change of tensile force in one direction, and compressive on the other, whereas that of a ship is subject to both tension and compresssion on the bottom and upper deck as she rises and falls upon the waves.

On referring to the experiments to which we have alluded, we arrive at this curious and interesting fact, that the joints of an iron riveted beam sustained upwards of 3,000,000 changes of one-fourth the weight that would break it, without any apparent injury to its ultimate powers of resistance. It, however, broke with 313,000 additional changes, when loaded to one-third the breaking weight, evidently showing that the construction is not safe, when tested with alternate changes of a load equivalent to one-third the weight that would break it.*

These results are probably not without interest as regards the construction of iron vessels, as they appear to be conclusive that time is an element in the endurance of structures when subjected to severe strains affecting their ultimate powers of resistance. It is difficult to determine or pronounce what is the correct measure of safety,

* *Vide* "Philosophical Transactions."

whether one-fifth or one-fourth the breaking weight, but we have sufficient data to be assured that every disturbance, however minute, in the molecular construction of bodies finally tends to their destruction, and it is only a question of time when rupture ensues. We may, however be assured that a ship, as well as a beam, is practically safe for a long series of years when the strains do not exceed five tons per square inch upon the wrought-iron plates of which it is composed.

Dr. Rankine has investigated this question, and in a paper read before the mechanical section of the British Association for the Advancement of Science at Bath, entitled, "On some of the Strains of Ships," he states that in previous scientific investigations respecting the strains which ships have to bear it has been usual to suppose the ship balanced on a point of rock, or supported at the ends on two rocks. The strains which would thus be produced are far more severe than any which have to be borne by a ship afloat. The author computes the most severe straining action which can act on a ship afloat, viz., that which takes place when she is supported midships on a wave crest and dry at the ends, and he finds that the bending action cannot exceed that due to the weight of a ship with a leverage of one-twentieth of her length, and the racking action cannot exceed about sixteen one-hundredths of her weight. Applying these rules to two remarkably good examples of ships of 2,680 tons displacement, one of iron and the other of wood, described by Mr. John Vernon, in a paper read to the Institution of Mechanical Engineers in 1863, he finds the following values of the greatest stress of different kinds exerted on the material of the ship:—In the iron ship—tension, 3·98 tons per square inch; thrust, 2·35; racking stress, 0·975. It follows that in the iron ship the factor against bending is between 5 and 6, agreeing exactly with the best practice of engineers, and that there is a great surplus of strength against racking. In the wooden ship—tension, 0·375 tons per square inch; thrust, 0·293. Here the factor of safety is between 10 and 15, which is also agreeable to good practice in carpentry. As for the racking action, the iron diagonal braces required by Lloyd's rules would be sufficient to bear one-third of it only, leaving the rest to be borne by the friction and adhesion of the planking.

From these inquiries it would appear that the strains are considerable on an iron ship—that for tension being 3·98, or 4 tons per square inch; thrust, or compression, 2·35 tons; and racking stress, 0·975 tons; evidently showing that a ship labouring at sea is subject to severe tests of repeated strains, independent of shocks which may occur from displacement of cargo or waves of greater magnitude, which generally succeed each other at certain intervals in severe gales. But be this as it may, it is necessary to have iron ships securely and strongly built.

Flexure and Crushing.—It has been ascertained that the effect of compression on any substance is to shorten its height and to enlarge its surface by increasing its bulk horizontally. Supposing, however, that the substance is confined and prevented from spreading in that direction, and it will then be found that the weight of one ton compresses wrought iron about $\frac{1}{10000}$ part of an inch; and in cast iron, which is much harder, we meet with this anomalous condition, namely, that a similar specimen is shortened or compressed $\frac{2}{10000}$ parts of an inch, being double that of wrought iron with the same weight. This arises, probably, from the porosity of its crystalline structure as compared with wrought iron, which undergoes a process of consolidation by hammering and rolling.

Another curious circumstance connected with wrought iron when submitted to compression is, that it will bear any amount of pressure provided it be sufficiently ductile. It, however, suffers distortion by a comparatively light weight, and its resisting powers are seriously injured with 12 tons per square inch. Beyond this it may be compressed to any extent, provided it be sufficiently plastic, by enlarging its base and shortening its height till it becomes a perfectly flat plate. With 12 tons its elasticity is much impaired, and it takes a considerable permanent set, which increases as the square of the load, and in most cases, where these effects are important, it is desirable, if not absolutely necessary, to keep within the limits of its elasticity.

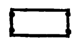
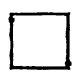
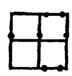
We have already seen that both the top and the bottom of a ship have to resist a force of compression analogous to that sustained by columns, and that being the case it is desirable that we should become acquainted with the resistances of wrought-iron of different forms in that direction. It is also necessary to ascertain the laws by which these resistances are regulated in the relative positions of the upper deck and the lower hull of a ship. Effectively to resist these forces, it is obvious that the covering plates below and the stringer plates above require to be stiffened, or, in other words, to convert them into a series of horizontal pillars, calculated to offer an equally powerful resistance to compression as they do to tension. It was for that object that the late Professor Hodgkinson undertook—in conjunction with the writer, when engaged in the construction of the Britannia and Conway bridges—a laborious series of experiments on the compression of wrought-iron plates and tubes which form the top of these immense structures. These experiments apply with equal force to the construction of iron ships as they do to tubular bridges, and we may therefore find it serviceable to offer a few remarks upon them.

In the earlier experiments it was found that round, square, and rectangular tubes, of a given length, presented nearly double the resisting powers when the same weight of material was applied in the form of a tube or cell than it did in the form of a solid plate. These facts were subsequently confirmed by Professor Hodgkinson's experiments, of which the following table is an abstract. (See Table, page 28.)

A plate employed as a pillar resists flexure in a much higher ratio than in the simple proportion of its thickness, such stiffness or strength being analogous to the transverse stiffness of a beam; hence, as in the beam, it will also be highly advantageous to distribute any given material in a pillar, in such a manner as to ensure the greatest possible depth in the direction in which it is liable to bend. Mr. Hodgkinson states that if the pillars are short as compared with their diameter, such precautions are unnecessary, the cubic inch of wrought iron cannot be put in better form, but if it were rolled into a very long and very thin plate, one inch broad, and placed on edge, the smallest force would bend it. If we shorten this thin plate by increasing its thickness, but maintaining the same height of one inch, we shall increase its resistance to flexure in proportion directly to the cube of the thickness, and in proportion inversely to the length, since the length will diminish in the same proportion as the thickness increases, therefore the strength will increase directly as the square of the increasing thickness, or inversely as the square of the decreasing length, until the plate arrives at such a thickness that it will fail partly by crushing. This law will now begin to vary as we go on increasing the thickness at the expense of the length; and ultimately, as we approach the cube itself again, the strength, instead of varying as the square of the increasing thickness, will cease to vary at all with the thickness; its strength will, therefore, have varied during these changes, as every power of the thickness between 0 and the square of the thickness, while the resistance itself would be represented progressively by every quantity between 16 tons and 0, the quantity of material or section and height having remained constant, so that n-square inches of sectional area on the top of a tube may resist any compression between 0 and $n \times 16$ tons, according to the form in which it is applied.

We should thus use the thickest plates we can get for the top of a ship or a tube, until their thickness was such that any variation in the thickness causes no corresponding variation in their resistance to compression; beyond this we get

RESISTANCE OF RECTANGULAR TUBES, ALL TEN FEET LONG, TO A FORCE OF COMPRESSION IN THE DIRECTION OF THEIR LENGTH.

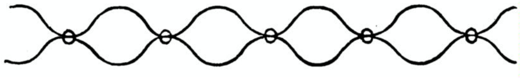
External dimensions of tube.	Thickness of plates.	Weight with which buckling or perceptible undulation was observed.	Weight of greatest resistance.	Form of section of tube.	Area of section of tube.	Weight per square inch of greatest resistance.
inches.	inches.	lbs.	lbs.		inches.	tons.
4·1 × 4·1	·03	...	5,534		·5040	4·9020
4·1 × 4·1	·06	...	19,646		1·0200	8·5986
4·25 × 4 25	·083	29,290	37,354		1·4840	11·2370
4·25 × 4·25	·134	46,314	51,690		2·3947	9·6360
8·175 × 4·1	·061	13,209	23,289		1·532	6·786
8·5 × 4·75	·264	...	197,163		7·326	12·015
8·4 × 4·25	·26 & ·126	99,916 (?)	206,571 = 92·2 tons.		6·89 (nearly)	13·3845
8·1 × 4·1	·059	37,401	43,673		1·885	9·877
8½ × 4¾	¼ (nearly)	...	...		8·3466	Not crushed with 11·12 tons
8·1 × 8·1	·06 (nearly)	15,897	27,545		2·070	5·926
8·37 × 8·37	·139	82,475	100,395		4·9262	9·098
8·5 × 8·375	·2191	...	198,955		7·7367	11·48
8·5 × 8·4	·245 & ·238	...	...		8·4665	Not crushed with 11·05 tons
8·1 × 8·1	·0637	56,630	70,070		3·551	8·809
8·1 × 8·1	·0637	46,635	82,027		3·551	10·312

no further advantage. If, however, we are compelled to use thin plates, we should arrange them so as to ensure depth to resist buckling. If one cubic inch, when rolled out into a long strip, so as to fail by flexure, were, for instance, formed into corrugations, it would in this form support considerably more than in the form of a straight plate,

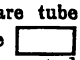
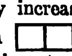
FIG. 4.

for instead of being a mere line in section, with no depth, it would now possess a depth equal to the versed sine of the corrugations, or equal to the distance between each convexity; and in this corrugated form we should attain the maximum resistance to pressure, viz., 16 tons, with our plates much thinner than when used straight. The depth would be still further increased if we folded our corrugated plate round upon itself, so as to complete a series of tubes, taking care to unite carefully the points of

FIG. 5.



contact. There are numberless familiar examples of stiffness obtained by such method of construction. An ordinary paper fan, and many household articles in tin, though constructed of thin and pliable material, are extremely strong and rigid from the depth acquired by the bending of the material. The domestic tea-board and dust-shovel are striking examples. It thus becomes a question, with a given section of material of given thickness, how to construct the strongest form of pillar or a series of pillars to resist crushing, and how near we can with this form approach to the limit of 16 tons per square inch.

Since a flat plate, for the reasons explained, will bend sooner than a curved plate, it would be concluded, naturally, that a round tube, of moderate dimensions and of given thickness and section, would be a stronger form than the same plate in a rectangular form, in which the resistance to crippling must depend solely on the four angles; and since the rigidity afforded by the angles is extended throughout the four sides of a rectangular tube, in some manner proportionate to the distance from the angles, it would be concluded that a square tube  would be stronger than a rectangular tube  constructed with the same plate, inasmuch as the central portions of the longer sides of the rectangle will be less maintained in form on account of their greater distance from the angles; similarly increased strength might be expected from this form  These assumptions were all submitted to experiment and confirmed.

For this purpose a number of tubes or cells of wrought-iron were constructed, all ten feet long, and either four or eight inches square, or of rectangular form about four by eight inches; their ends were perfectly flat, and they were compressed, by the intervention of a lever, between two parallel discs of steel, with arrangements for maintaining the pressure perfectly vertical, the cells being supported laterally. The direct object was to ascertain the value of each particular form of cell, and to ascertain the resistance per square inch of section in each case. The lateral dimensions of these cells are so large, that with a length of ten feet the pillars were not destroyed by flexure as in a long pillar, but by absolute buckling or crushing; the strongest possible form should, therefore, give about 16 tons per square inch of section.

Similar experiments were then made with circular cells, under precisely similar circumstances for comparison. The cylinders varying from 1½in. to 6in. in diameter; the diameter being so small in some cases as compared with the length, some of these pillars failed by

flexure, and followed the laws of long pillars, the resistance increasing nearly inversely as the square of the length; but where the diameter was six inches, the length being ten feet, flexure could not take place, and the cells failed by buckling or crushing, as in all the rectangular pillars, and in such pillars the strength is independent of the length.

To show how the failure in the rectangular and cylindrical tubes took place, the annexed drawings, as represented by Figs 6, 7, 8, and 9, may be useful.

FIG. 8.

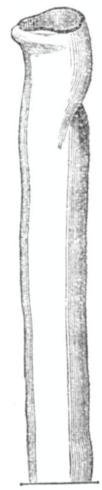


FIG. 6.

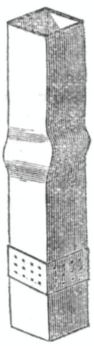


FIG. 7.

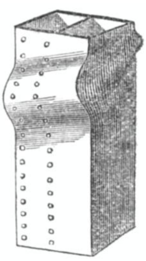


FIG. 9.

From the foregoing researches it will be observed, that in order to attain the maximum powers of resistance to compression in the use of iron plates in construction, that the square box with thin plates next to the plate itself is the weakest experimented upon; the next in the order of strength is the rectangular form with a division across the centre as at *a*, $\boxed{a}\boxed{}$ but the best distribution of the material is in the cylindrical form. This latter cannot, however, be accomplished conveniently in ship building, but the rectangular or cellular construction is applicable in all cases where resistance to compression as well as tension is required in the hull and upper decks of vessels.

LASTLY, ON THE DISTRIBUTION, STRENGTH, AND VALUE OF WROUGHT-IRON PLATES AND FRAMES AS APPLIED TO SHIPS AND OTHER VESSELS.—In this department of inquiry, we have not only to consider the nature of the strains to which the sides and other parts of a vessel are subjected, but we have to determine the distribution of the material in the different parts of the vessel, so as to establish as nearly as possible perfect uniformity of strength. What we mean by uniformity is, that the resistances in any one part of the vessel should be proportioned to the strains on any other part, and that no waste of material should take place beyond what is necessary to maintain the balance of the opposing forces of strain and resistance. In our endeavour to determine the superior value of iron as a material of which vessels should be constructed, we have not entered into the question of distribution. This is, however, one of the most important elements of construction, and in order to approximate as closely as possible to uniformity of strength, we have to apply the material in such forms and positions as will effectually resist all the various strains to which the vessel is subjected.

It will be observed, that in the preceding investigation we have invariably viewed the question of vessels as they are now built, being subject to much severer strains than formerly when built of wood. The present class of steamers are nearly double the length that they were formerly as sailing vessels; and the depths are much less in proportion, so as to render their powers of resistance to the action of the sea less than one-half that which would have been the case had the form of construction been upon the old principle. This being the case, a series of strains of double intensity are brought into existence, and these have to be provided against if we are to have safe vessels on the new principle of construction.

All these changes are elements of weakness unless met by an equable distribution of the material, and it is on this principle that we have treated the new build of vessels as hollow girders. Let us, for example, take a first-rate ship of war as built seventy years ago, such, for instance, as the *Victory*, and we have:—

	feet.	in.
For the length between the perpendiculars...	260	0
Breadth of beam	60	1
Depth	53	10

This according to formula $W = \frac{adc}{l}$ would—if built of iron and duly proportioned with sectional areas of 800 square inches, and if suspended on two points, stem and stern, sustain a load in the middle of 9,785 tons, or 19,570 tons if equally distributed.

Taking the same sectional area, and applying it to a vessel similar to the *Warrior*, and we have, with the same areas and the same constant 60, the decks being duly proportioned to the bottom,

	feet.	in.
For the length	380	0
Breadth	58	4
Depth	42	0

Hence $W = \frac{800 \times 42 \times 60}{380} = 5{,}305$ tons as the breaking weight in the middle, or 10,610 tons equally distributed, which is little more than half the strength of the former. From these facts it will be seen that we require an increased sectional area of 675 square inches in addition to balance the resisting forces of the two ships, which evidently shows that, increasing the length and diminishing the depth, the present build of vessels, when constructed of the same material, requires an increase of strength in the ratio of 1475 : 800 or as 1 : ·542. But this is not all, as we find from experiments on the effect produced on wrought-iron when subjected to alternate changes of load, that to build a durable vessel we should have to calculate the sections of the hull and upper deck, and to render it endurable under the varied strains to which it is subjected these should not, on the sectional area, exceed five tons per square inch.

A vessel thus constructed would, in our opinion, be perfectly safe under every condition when exposed to the action of the sea, but, if stranded upon a rock or shelving beach with coal and cargo on board, she would be severely tried by the force of impact when continuously rising and falling, and subjected to the influence of a tempestuous sea. But even in this precarious position it is very questionable whether or not she would go to pieces. On the contrary, we are of opinion, if constructed with water-tight bulkheads, strong longitudinal keelsons, and double bottoms, that in nine cases out of ten she would hold together, and save the lives of all on board.

In the distribution of the material there is another consideration of great importance, and that is, that in all bodies in the form of beams, whether hollow or solid (they follow the same law as regards a transverse strain), the strains are always greatest in the middle, and progressively diminish to the points of support at either end. These facts are self-evident, and show in the case of an iron ship that the same thickness of plates is not required when working from the centre at midships to the stem and stern. In fact, they should taper and be reduced in thickness in the

ratio of their distances from the centre till they reach the extremes at each end. Theoretically this is true, but in practice we have to consider how much the thickness can be reduced without danger to the structure, and in these we may here observe that the reduction should not exceed one-third between the centre and the two extremes. Or, in other words, if we assume the strakes or sheathing plates of the bottom and round the bilge to the height of the interior floor, or one-fifth of the depth, to be $\frac{7}{8}$th of an inch thick, it then follows that their thickness may be safely and progressively reduced to $\frac{5}{8}$ths thick towards the bow and stern. The same reduction to $\frac{5}{8}$ths thick may be made from that point, one-fifth of the depth, to the neutral axis of transverse strains, or about half-way up the ship's side, when they should again increase to $\frac{7}{8}$ths thick on the top strakes at the deck, on each side, where they have to perform the office of stringers under the action of the two forces of tension and compression.

From these remarks it is obvious that a careful distribution of the material is a desideratum of considerable importance in shipbuilding, and although it may be necessary in some constructions to make deviations, it is nevertheless essential that the law of strains should be carefully observed and weak parts effectively guarded against.

It will not be necessary in this communication to give drawings in illustration of these statements, as from other data the question may be rendered sufficiently explicit to enable the iron shipbuilder to proportion the parts in the ratio of the strains, and to afford to the ship, as a whole, ample powers of resistance to the forces by which she may be assailed; care however being taken to provide for wear and tear, oxidation, and all those other influences which tend to weaken the ship.

I would have entered more on this question, but I have already exceeded the limits of an ordinary paper, and must reserve for some future occasion the further development of a subject of such deep interest in connection with naval construction. I may, however, state in conclusion, that the iron navy of this country is destined to take the place of the "Hearts of Oak," and become—as many now living may hope to see it—the dread of our enemies, the bulwark of commerce, and the harbinger of peace.

DISCUSSION.

Capt. HENDERSON said—As an old sailor he wished to offer some observations on the construction of ships, but especially of light-draft steamers for India, in which he had had some twenty years' experience, and gained much information from Mr. Fairbairn. With reference to the diagram on the wall of a box-girder or deck-stringer, by which Mr. Fairbairn strengthens the upper decks of ships, he (Mr. Henderson) stated that he had practically adopted this system in river steamers of the Assam and native types, the bottom forming the bow, with seven keelsons, on the bow-and-string principle of construction. The Government sloop steamer, built for the Indies, was on the reverse, *i. e.*, the bottom formed the string, and the arched girder the bow above; and on being tried on the Thames in 1861, with full power of engine, the bottom bent downwards. The arched girder was strengthened before shipment to India. Similar trials on the Thames of the *Assam Nautilus*, also built by himself (Capt. Henderson), proved her speed and steering power; and her strength had been tested by grounding on the banks of the Thames, and lying across dock gates, with 40 tons on board.

Mr. JOHN HAWKSHAW remarked that little room was left for observation on the paper, because it dealt so largely with the elementary principles of construction which were generally known and acknowledged. He should, perhaps, best show the extent to which he agreed with his friend, Mr. Fairbairn, by mentioning the principal point on which he differed from him. The paper advocated what he would call the old-fashioned principle of putting together iron plates by punching the rivet holes, as better than that which he believed he (Mr. Hawkshaw) had adopted, perhaps more extensively than any other engineer, viz., by drilling. He differed entirely from the views laid down by Mr. Fairbairn in this paper. He (Mr. Hawkshaw) had used the method, which his friend Mr. Fairbairn must permit him to call the sledge hammer principle, for many years, and he had come to the conclusion that this punching principle, whether in shipbuilding or bridge-building, or in any other of those different constructions to which iron was now applied, was very faulty. He (Mr. Hawkshaw) had for some years past adopted the principle of drilling the plates, and he had no hesitation in saying, from his experience, it was greatly superior to the work which was produced by punching. He had no hesitation in saying that if the Britannia-bridge, instead of being put together by punched plates, had been put together by drilled plates, there would have been a better result by 20 or 25 per cent. There was considerable difficulty in the first instance, when he required manufacturers to drill instead of punch, viz., the increased cost which the manufacturers thought would be entailed by this plan, but such was not proved to be the case. Gentlemen who had constructed iron work for him, and who had adopted the principle of drilling instead of punching, had stated publicly, and he (Mr. Hawkshaw) was therefore justified in asserting, that having once gone to the expense of providing drilling machinery, it was cheaper to drill than to punch. He had had machinery constructed which would drill from 30 to 50 and even 80 holes at once, and the work obtained by that method was very superior to that on the old plan. A simple experiment would show this. Take a number of plates that had been riveted together, having been previously drilled, and saw them through the line of the rivets, and do the same with a similar number of plates riveted after being punched (and he had tried it himself), and it would be found that in the one case the line of demarcation between the rivet and the plates could scarcely be traced, while in the other numerous interstices not filled up between the rivet and the plates were frequent. If they had merely to rivet two plates together by punching, no doubt by adopting the principle of compression, which he agreed with Mr. Fairbairn was better than the hammer, these interstices might be filled up; but when a large number, say ten plates, had to be put together, there the punching system failed, whilst with the drilling system the ten plates could be put together with the same perfection as two. As that was the only point on which he differed from the views expressed in the paper, he might be excused calling attention to it. With regard to the paper generally, it laid down a great number of principles which were universally acknowledged, but it did not, as it appeared to him, touch that very difficult question as to what was to be the mode of construction for iron ships of war. He had himself, as far as he had had time and opportunity, given considerable thought to that question; and he was free to confess that the more he thought about it the more he found it surrounded with difficulties. He, therefore, could not agree with those gentlemen who thought that by this time somebody or other ought to have determined what was the best form of construction for a ship of war. Before they determined that question, they must settle previously which of two principles was to be adopted, viz., whether the armour of a ship was to form part of and conduce to the strength of the ship, or whether the armour of a ship should be treated as something extraneous to the ship, to be placed upon it or hung about it, to be donned or doffed as occasion required. Until these questions were answered he did not see how they were to arrive at the proper form of construction for ships of war. So far as he had had opportunity of judging—and he had seen *La Gloire*, as well as the *Warrior* and other specimens of war ships, and the various targets that had been experimented upon at Shoeburyness—he thought

there was a confusion of ideas as to what was to be aimed at. It did not appear to be settled whether the armour should form part of the ship, and therefore add to its strength, or whether it should be something merely to defend the ship itself. This must, however, be settled before ships could be built on an intelligible principle. He gave this opinion deferentially, because it was a very difficult subject, and possibly never would be solved without the terrible experiment of a great war. So far as he had been able to come to a conclusion on the subject, he did not see why the armour of a ship should not be made conducive to its strength. He was honoured by the committee appointed to consider that subject by being requested to construct what was called a target. It was not in fact a mere target he had constructed, but a combination of iron plates, to illustrate his own views of war-ship construction. He stated distinctly, in writing to the committee, that it was not put forward simply as a target, because if they wanted a target, a thing merely to resist shot, it was the simplest of all things to make. All they had to do was to make something as like an anvil as they possibly could, a large lump of iron of the best texture. This would doubtless resist shot. But the problem they had to solve was how to introduce this enormous mass of iron into the fabric of the ship, and whether it could not be conducive to the strength of the structure. This was not easy to do. The question, however, must be solved before they could set about building a ship of war.

Mr. JOHN GRANTHAM would take the liberty of intervening between his two friends, Mr. Fairbairn and Mr. Hawkshaw, on the question of riveting, a subject to which he had given great attention, and on which he had lately read a paper before the Institute of Naval Architects. He did not wholly agree with Mr. Hawkshaw on all his points. He believed that in bridge-building and all straight structures it was not difficult to drill the holes successfully, and much better than if they were punched; but the paper dealt principally with ship-building, and there a different condition of things arose. They had scarcely any straight plates in a ship, but they were for the most part of a curved form. The plates had to be applied singly, one after another, under difficult circumstances, and hence drilling could not be readily performed with success, and he considered it objectionable. In putting together two plates no advantage could be claimed for drilling, for when the two plates were put together, in drilling a burr formed, and the oil and dust from the outer plate fell in between the two plates; that accumulation and the burr had to be removed, and for this purpose the plates must be separated; and he could therefore say, as far as his own experience went, that Mr. Fairbairn's remarks as applied to ship-building were correct; but with regard to straight girders, or bridge work, with which Mr. Hawkshaw had been principally engaged, drilling was by far the best process with a number of plates. There was no question that the holes could, by drilling, be made more accurate than by separate punching, He had hoped that the paper would have dealt at greater length with some of the points of importance occupying public attention, and that it would have entered more largely on the question of the construction of ships of war. He thought the paper had not gone sufficiently into that subject. The great question of the day to be determined was, were our ships for the Royal Navy to continue to be built of wood, or were they to be built of iron? In the merchant navy this question had long been settled. It had long been settled that a ship was a girder in principle, and the nearer they approached to it the better. It had long since been settled that a ship must be strongest in the centre and lightest in the ends, but they had not yet settled whether a ship of war should be built of iron or wood. Some practical men had gone halfway in this matter, by introducing iron in one part and wood in the other. In his judgment that was an unfortunate combination. If iron was good, let it be iron; if wood was good, let it be wood—but do not combine the two together in the unfortunate way in which he thought it had lately been done. The great difficulty with regard to iron ships had not arisen upon any difference of opinion as to strength—that had been settled thirty years ago. The durability of an iron ship had also been long since settled. The commercial advantages of iron in ship-building had been long since acknowledged by the universal testimony of the mercantile community; but there was one question which was not yet settled, and that was the great question of fouling. The whole navy of Great Britain at the present day he believed would have been built of iron if the difficult subject of fouling had been got over. That was the real mischief now hanging over iron ships. Referring to another part of the subject, whether the iron plating was to be made part of the strength of the ship or not, they must determine whether the rest of the structure was to be of wood or of iron? If they had wood, all they could do was to hang the plates on the sides as a mere protection. If they made the rest of the structure of iron, then came the question whether the armour plating might not be made part of the strength of the ship? Why should they not make effective use of this ponderous protecting mass of iron in giving strength to the ship. Why should it be thrown away? Why should not the whole ship be built of iron? Were they still to adhere to that which the mercantile community had long condemned, and still cling to wood in the construction of the hulls of the ships of war? More especially, considering that all war ships were built for steam engines, for which a wooden structure was unfitted. Then came the question of fouling. He had been for 40 years connected with shipbuilding, and for 30 years had given his attention to the subject of fouling of ships, and he ventured to assert that, in spite of all the inventions and suggestions which had been brought before the public, they were no forwarder at this day than they were 25 years ago. He would call attention, however, to the fact that there were ships built half of iron and half of wood, but not in a manner adapted for some of our vessels of war. The ribs and many other parts were of iron; but the ship was afterwards covered with wood. Those ships had been found the best for tropical climates as regarded the fouling of the bottoms. They possessed many of the advantages of iron ships, and got rid of the evil of fouling. Ships of this class had been found exceedingly serviceable. He, however, would suggest an additioual step in this direction, and that was to build the whole ship of iron, and afterwards sheath her with wood, and copper her under the water. They had proofs that this system was excellent; it prevented fouling, and secured all the practical advantages of an iron ship. He believed if this had been done years ago there would not have been a single wooden ship in the navy, and the whole contest would have been at an end.

Mr. ROCHUSSEN said, as he was connected with several continental iron and steel manufacturers, he might be allowed to say a few words on the strength of iron, the use of which, as a material for ship-building, together with the employment of steam as a propelling power, was largely extending, not only in this country, but also in France and America. The average tensile strength of the ordinary iron used for ship-building was $32\frac{1}{2}$ tons in the line of the fibre, and $31\frac{1}{2}$ tons across the fibre. He had with him the details of experiments made by Mr. Fairbairn, which corroborated those figures. He thought that steel might with advantage be introduced into plates for ships; and it was worthy of consideration how far this lighter material might be beneficially employed. The steel might be rolled. It was simply a question of power. If, by so doing, 400 or 600 tons weight could be saved in the plating of a ship like the *Warrior*, it would afford great facilities for carrying a heavier armament.

Captain SELWYN, R.N., would say a few words on the question of strains to which ships were subject at sea. The strains were not as pointed out by the author of the paper

though he (Capt. Selwyn) was aware that such were in accordance with the views generally held, which supposed a ship being possibly suspended between the crests of two waves. Those who advanced that idea seemed to forget that which was sufficiently patent to all seamen, viz., that a ship in such a condition immediately sank in the water to a medium line of flotation. There were only two circumstances under which the waves could so operate: one was when from a gale or swell at the stern the waves came in that direction, and the other was when a vessel was driven by a gale against a head wind. Every good seaman knew it was madness to drive a vessel ahead against a heavy gale of wind, for if they did so invariably the bows shot out 50 or 60 feet unsupported in the air. Under those circumstances strains were brought on the vessel such as nothing ever built by human hands could hope to stand against. A good seaman would either lie-to or make only moderate speed. It was true in modern days the outside pressure for quick passages sometimes led seamen to act against their better judgment, but they knew they did so at the risk of the vessel breaking up. He had spoken of the sea coming up by the stern, and under such conditions no such strain as had been described need be feared. The vessel, it must be remembered, was going ahead at a given rate, and the wave and undulation—for he made a distinction between the two—the wave rose and fell, but its particles were not propagated forward as fast as the undulation. Those waves coming on the stern found the vessel progressing in their own direction, and they then only gently lifted the stern and passed under the ship, not causing any great strain, and seldom pooping the vessel unless some false manœuvre had been performed. With regard to the question of thickness of plates for ships, he begged Mr. Fairbairn to consider whether or not he could safely recommend increased thickness in the midships, and decreased thickness at the ends, considering that it was not so much the effect of the strains that was to be feared as the results of concussion when a vessel grounded on a bank and then lifted with the sea. After the battle which had been so severely fought between wood and iron, compromise was a very agreeable thing to hear of, but he was afraid that Mr. Grantham had not sufficiently considered the effect of shells in his recommendation of a sheathing of wood, which he was sure would be stripped off in ten minutes after the vessel had been in action, or would be set on fire by shells; and even if the wood were rendered partially incombustible, as no doubt it might be done, the smoke from the smouldering wood would be sufficient to render the vessel untenable.

Mr. GRANTHAM said the wood sheathing would only reach to the edge of the armour plates, several feet below the surface of the water.

Captain SELWYN added that trial had been made of that plan, and it did not answer when armour plates were concerned. He had read a paper before the Institute of Naval Architects on the galvanic action of the bottoms of ships. It was proved that galvanic action could not be interrupted; as it went on between the iron and copper and salt water, either by strips of intervening material or otherwise, and in spite of every device hitherto thought of. It did go on, because though there might not be metallic conduction, yet there was conduction through the water which was sufficient to set up and carry on galvanic action. The effect of this was accumulated at the point of contact with the armour plates. That action was not less to be feared in the lighter construction for mercantile purposes, and the rivets constantly dropped out, as in the case of the *Harbinger*. In some instances the galvanic action had been stopped by protecting the bottom with asphalte, and in one case by a coating of brickwork covered with asphalte. With respect to the bricks, they contributed nothing but an objectionable weight, and he thought a better material than asphalte might be employed for preventing the salt water from acting as a medium of setting up galvanic action. These matters were so important in the advanced state of shipbuilding that calling attention to them was not out of place.

The Duke of SOMERSET, in proposing a vote of thanks to Mr. Fairbairn, said he was sure those who had heard the paper, and the discussion that had followed on it, would admit that very many important questions had been raised. He further thought it would be admitted that the Admiralty had at least been placed in some difficulty, when called upon, at short notice, to provide the best ships of war. They had been told that evening that it was very difficult to say what was the best possible ship of war, by persons who had been inquiring into the subject for many years. They were told that the Admiralty ought to provide ships of the best iron, and projectiles of the best steel, and yet, when they came to inquire as to what was the best iron and the best steel, there was no conclusive knowledge to be obtained. Dr. Percy, in the preface to his book on Metallurgy, stated that as regarded the chemical nature of iron, our knowledge was very imperfect; and as to steel, still more so. Then they came to the mechanical tests: and the question then arose how far did the tests injure the iron? That question was very important, and one which he did not think had been clearly settled. He wanted to know how far they could proceed in testing without injury. It was proposed in the paper that iron vessels should be tested. Would they for that purpose place the two ends of a vessel in the position represented in the drawing, in order to see whether or not she would break; or would they test the plates? Would such tests, if the vessel withstood them, leave the ship or plates uninjured? and could they be sure that no injury had taken place? With regard to the testing of chain cables also, the same question arose—were they quite sure, in the testing of chains, how far they might test them with safety? In regard to the proving of cannon, again the same question arose—their testing might injure the metal. As to steel projectiles, how were they to test them? Were they to fire against iron plates every time? Were they to break a number of plates in order to break the projectiles? Then as to the construction of the ship of war. They had been told that the Admiralty were advocating a wrong principle, and that they ought to make up their minds and build entirely with either all iron or all wood; and another gentleman had told them he had successfully built iron ships, and covered with wood. In attending the meeting that evening, he was in hopes of learning that some of these conflicting questions were about to be solved, and that he should have gone to the Admiralty in the morning, and informed his colleagues that the whole question had been set at rest. But he was still left in difficulty. They were told that iron was the best material for resistance, and that they ought not to combine iron and wood together. That had been the opinion of the Admiralty, and it was the opinion also of Mr. Fairbairn. They tried experiments at Shoeburyness, but Mr. Fairbairn had told them they must put a certain quantity of wood behind the iron, in order to obtain an effective resistance to shot. This evening, however, some gentlemen had told them not to use any wood at all. This showed that the subject was still surrounded by numerous difficulties. He would say he was delighted to have heard this discussion, and he hoped they should at some future time have another paper devoted to the consideration of some one or two of the points on which they desired to be enlightened. Instead of entering into general questions let them take up one great question and see if they could arrive at satisfactory results upon it. In the meantime he had great pleasure in proposing a vote of thanks to Mr. Fairbairn for his very able paper.

The vote of thanks having been passed,

Mr. FAIRBAIRN said the paper was not intended to be limited to the question of armour plate and ships of war,

but it applied also to vessels for commercial purposes. The main object was to show how, both in the navy and mercantile marine, the material could be best distributed in order to obtain strength in the ship. With regard to riveting, he was quite aware there was difference of opinion; but his own feeling was, where riveting was well executed, they could not have a better test of the quality of plates than by punching, and, where the holes were well punched, he preferred them to the drill, as he found that in drilling the holes were not always exactly coincident. Then as regards ships of war, he hoped on a future occasion to bring forward another paper on this subject, which he trusted would lead to a discussion that would realise to some extent what the Chairman had suggested as important, viz., something like certain information for the Admiralty to rely upon in the construction of ships. He should do his best to accomplish that object, and from the experience he had had he might state that he was satisfied iron was a better material than any other for building ships either for war or mercantile purposes. Under all these circumstances, he hoped the Admiralty would persevere in what they were now doing in the construction of iron ships. On the question of armour plates, he would say, if they were to have 300 or 400 pounder guns it was a question with him whether it would not be better to be without armour plates altogether, and let the shots go right through, because they were limited to a certain thickness and weight of plates; and if they were to cover vessels from stem to stern, and five feet below the water line, they would not be able to carry plates that would resist those large guns. If that description of artillery was used, his opinion was they would have a more secure and better navy without the iron plates than with them.

The Secretary called attention to some photographic copies of engineers' drawings, lent by Mr. W. Willis, of Bath-street, Birmingham. By means of a photographic process, the details of which are not yet published, copies of drawings can be made rapidly and cheaply of the same size as the original. The original drawing is in no way injured by the process, and the copy is produced by simple superposition over the chemically-prepared paper, and is a positive copy direct without the intervention of a negative.

The Secretary also called attention to a model of a tilt hammer, moved by means of a knee joint, driven by direct action of a steam piston.

DUBLIN INTERNATIONAL EXHIBITION, 1865.

The Committee of the International Exhibition for 1865, have great gratification in publishing the following correspondence, conveying Her Majesty the Queen's gracious assurance of support to the undertaking:—

Dublin Castle, Nov. 19th, 1864.

My Dear Duke,—After the interview I had the honour of holding with the deputation representing the Committee of the Dublin International Exhibition for 1865, I wrote to Colonel the Hon. Sir Charles Phipps, submitting the request that her Majesty would be graciously pleased to allow the Exhibition to be placed under the Royal patronage, and your Grace will be gratified to learn, from the enclosed correspondence, that this request has been most promptly complied with.—I am, yours very faithfully, (Signed), Robert Peel.

His Grace the Duke of Leinster.

Dublin Castle, Nov. 15th, 1864.

My Dear Sir Charles,—A deputation comprising the Duke of Leinster, Sir George Hodson, Bart., Sir R. Kane, Mr. Dargan, and several other members of the Committee of the Dublin International Exhibition for 1865, have just had an interview with me for the purpose of conveying the expression of their hope, through their Chairman, the Duke of Leinster, that her Majesty would be graciously pleased to allow the Exhibition to be placed under her Royal patronage.

From the enclosed prospectus it will be perceived that the enterprise is no longer of a purely speculative character, as it promised to be if it continued in the hands of the directors of the Winter Garden Company.

That Company has now nothing to do, as the Duke assured me, with the undertaking, and indeed many of the names on the Exhibition Committee are a guarantee of the respectability and public spirit which has been elicited in support of the movement.

I hope it will not be considered that I have gone beyond my duty in venturing to request that you would take a fitting opportunity of submitting this request for the patronage of the Queen to the notice of her Majesty, and there can be no doubt her gracious compliance would not only be most valuable to the prospects of the Exhibition, but that it would have the effect of giving a salutary impetus to the spirit and loyalty of all who are interested in the welfare of this country.—I am, &c., &c.,

(Signed) Robert Peel.

Col. the Hon. Sir C. B. Phipps.

Windsor Castle, Nov. 17th, 1864.

My Dear Sir Robert,—I have had the honour to lay before the Queen your letter of the 15th inst., and the objection, to which on a former occasion I alluded, having been removed, I have received the commands of her Majesty to say that she is happy to be able to accede to the request contained in your letter, and to sanction the announcement of the Dublin International Exhibition as under her Majesty's patronage.

The Queen wishes the promoters of this patriotic undertaking every success.—Sincerely yours,

(Signed) C. B. Phipps.

Right Hon. Sir R. Peel, Bart.

Fine Arts.

Exhibition of Industrial Art in Paris.—This exhibition, which is now open in the Palais de l'Industrie, in the Champs Elysées, and which will continue so until the end of the year, is got up by one of the societies formed to aid the progress of art as applied to industrial purposes, and embraces specimens of the ingenuity of the past as well as of the present time. There was some delay in completing the arrangements, but at the present moment, although the collection is not large, it presents considerable interest. It occupies the whole of the central portion of the building, which is laid out as a garden, and all the objects are seen to the greatest advantage. The principal objects are contained in three large square pavilions, which occupy the centre and two ends of the garden. That in the middle contains some remarkably fine specimens of galvano-plastic work from M. Oudry's works, at Auteuil, where the great fountains, candelabra, and other objects for the city of Paris, are submitted to the electro process, and of which we gave a report from personal inspection in the pages of the *Journal* some months since. The most conspicuous specimen in M. Oudry's collection, is a reproduction of an alto-relievo from the triumphal arch of Constantine; this specimen of galvano-plastic art is no less than twelve feet high and nearly nine feet wide, and weighs nearly four thousand pounds English. The mould was taken in gutta-percha, from a plaster cast. This noble work is surrounded by a fine collection of electro bronzes—statues, statuettes, busts, and ornamental works, iron castings covered with copper by M. Oudry's peculiar process, specimens of plate rolled after deposit, spikes and nails for ship-building covered with a thick coat of copper, and other similar objects; also a number of articles painted in imitation of bronze with M. Oudry's peculiar bronze pigments. A second pavilion contains a most remarkable collection of antique objects of art industry from the celebrated museum of M. Le Carpentier, whose antiquarian wealth approaches that of M. Sauvageot, whose collection is now in the museum of

the Louvre. The selection lent by M. Le Carpentier to the exhibition contains specimens of almost every kind, from the carved runic staff to the royal game of goose, which Louis XIV. played at when a child (this latter is, however, the only object not of importance in an artistic point of view). The articles are of all ages and countries, and include works of metal, wood, and ivory—jewellery, china, faïences, enamels, terra-cotta, and embroidery. The metal work and carvings are, perhaps, the most remarkable of all, but the whole collection is extremely choice; the case of French enamels is especially noticeable, and some of the small arms of the best Italian period are very beautiful. Amongst the iron work is a shuttle, pierced and engraved most admirably—the elegant instrument with which some aristocratic Ariadne of the fifteenth or sixteenth century made the mantle of her liege lord. The expenditure of so much art on such an object marks curiously the change that has come over the habits of civilised people. The collection of retrospective art includes contributions from other virtuosi, and also from dealers in antiquities. The third pavilion covers a selection of fine specimens of modern art, made by the society from amongst the objects sent for exhibition; and each visitor on entering receives a printed ticket, which entitles him to a chance in the lottery which is to take place at the conclusion. It is fair to mention here, seeing that the objects of the society are purely patriotic, that the price of admission is half a franc on ordinary days, one franc on Friday, and five sous on Sunday. The exhibition, happily, does not contain a mass of the common *articles de Paris*; almost every stand has something in the way of novelty or improvement to recommend it, at any rate the exceptions are the minority. The class of wares best represented, perhaps, are faïences; there are some very beautiful specimens of ornamental porcelain, but the fashion of the moment is for earthenware, and naturally, the manufacturers are making great efforts to rival the productions—now so well known here—of Minton and other English makers. French ornamental wares of this class are not remarkable for colour; in this they are far behind Staffordshire. But the Parisian and other potters are making great strides in the production of panels and other pieces of ware for decorative purposes. The greater portion of these are imitations of Della Robia or other ware, the best are produced after original designs in the flat, somewhat affected, but graceful manner of Hamon, who himself has not disdained to lend the aid of his pencil, as Flaxman did, in the potter's service. The introduction of figures and landscapes on faïence slabs, in carved frames, has recently, may be parenthetically observed, become quite the fashion in the houses of the rich in and near Paris; and, in some instances, similar ornaments have been introduced into halls and vestibules and exterior walls, and with charming effect. The number of exhibitors in this class is not great, and when we mention A. Jean, who has a house in London, Deck, A. Gouvrion; Masson, late Ollivier, established in 1742; Devers, an Italian; and Collinot and Co., all of or near Paris, we believe we have exhausted the list. (We may here note that there is not yet any catalogue of the exhibition.) Messrs. Collinot present a novelty in what is called *émaux cloissonnés*, and have covered their process by a patent; the designs, besides being slightly raised above the ground of the vase or other object, are marked by a very decided outline, hence the name selected for this new style of ornamentation. It is worthy of remark that the makers of porcelain and other fixtile ware have of late borrowed the very artistic habit of the Chinese, in mounting their best pieces on wooden stands carved in appropriate forms. It is marvellous how much more appearance of value a beautiful vase acquires by this treatment. Another sign of the time is to be seen in the iron works in this exhibition, which includes some very fair examples of pure hammered work as applied to the furniture of fire-places, lamps, and other domestic objects; some mere reproductions of the antique, others exhibiting truly artistic taste without conventionality. We can no more expect *repoussé* work to replace casting and other modern modes of ornamentation than we can look for the resuscitation of the post-chaise in competition with the railway, but the hammering of iron, or other metal, into graceful forms is so high a branch of industrial art that it is pleasing to find it not quite neglected—especially when we take into account its unrivalled effect. The exhibition is decked with some very fine specimens of tapestry from the Gobelins, Aubusson, and other looms, and in juxtaposition with these semi-artistic productions, are some very good specimens of the machine-made carpets and tissues of a company established at Meaux. Among the miscellaneous objects is a new kind of fuel, composed of tan and coal-dust, recommended for all kinds of fire-places, but which seems to have slipped by accident into an exhibition of industrial art; a system of lighting establishments by means of petroleum oil forced through pipes of small diameter by means similar to those used in the moderator lamp; and a new bathing machine, or boat, which has quite charmed the Parisians. This last novelty consists of a very light frame or basket, rendered buoyant by means of cork or other floats, and propelled by a screw; the bather lies at full length, with his head on a pillow, and works the propeller by means of a winch; and, as the axis of the screw is jointed and provided with discs, against which he places the soles of his feet, he can guide his bark wherever fancy directs. Some of the *Baigneuses*, as these new toys are called, are floated by means of four or more silvery-looking swans, and have been dubbed Leda's cars. The *Baigneuse* promises to be a success, as it is already being made the butt of a good deal of light wit; the prospect of going to sea in a sieve is charming, says one writer.

Manufactures.

Paper Making Materials.—A society has been formed in France, having for its object the investigation and discovery of vegetable fibres to be used in lieu of rags for the manufacture of paper, and for the organization of mills which should furnish the pulp-stuff to the associated makers. The communications already made on this subject have been referred to the general committee of paper makers as matters for careful inquiry and further proceedings at future meetings. The esparto grass, of which some 40,000 tons were exported from abroad for paper making last year, has been found growing along the coast of Cumberland, and local paper makers are carting it to their mills in great quantities, at the merely nominal price of carriage, instead of having to pay five guineas per ton for Spanish.

China Grass.—The French manufacturers are experimenting largely upon the use of the nettle fibre known under the popular name of China grass. We have been favoured with a sample of fabric made with an equal mixture of 100 kilogrammes of Surat cotton and the same quantity of China grass at Rouen last month. The French papers are freely discussing the report of the Rouen Chamber of Commerce of the 18th ult. on the subject.

German Carpets.—Some of the largest carpet manufactories in Germany are established at Hanau, and the carpets made there are said to surpass those made in England, and have a high reputation even in Paris. One of the best known and most extensive carpet manufactories in that town is that belonging to Bernus Leister and Co., especially as regards the finer kinds, which are highly esteemed both for the fastness of the colours and the good taste of the designs. This establishment employs a steam-engine of 20 horse-power, about 150 men, and 100 women. The greater part of the carpets manufactured in Cassel are bought at the Leipsic fairs for the Danubian Principalities. The above-mentioned firm employs 60 or

70 looms for spinning yarns, and altogether about 350 workpeople. Thirty or forty workmen are now employed in carpet weaving in smaller establishments in the city of Cassel.

Colonies.

THE BULLER COAL-FIELDS (NEW ZEALAND).—Steps are at length being taken by the Nelson Government, to open out these extensive coal fields. As it is impossible to raise the necessary capital to work the mines in a profitable manner in New Zealand, the authorities are about to send Mr. J. Burnett, who has had considerable experience in coal mining in England, to London, to form a company and raise the necessary capital; this gentleman will be furnished with plans, views, &c., of the district, and will also bring several tons of the coal with him. There can be no doubt as to the richness and extent of these mines.

ELECTRIC TELEGRAPHS (NEW ZEALAND).—The general Government are about to lay down the electric telegraph from Auckland to Dunedin, a distance of about 1,000 miles; although possibly the native war may interfere for some time with its construction in the Northern Island, that portion running through the South Island from Nelson, *via* Picton, Christchurch, &c., to Dunedin, will, it is hoped, be in active operation within a few months, contracts for poles, &c., having been already accepted; whether the rocky deep bed of Cook's Straits will be suitable for a submarine cable remains to be tested by survey and experiment. The distance from land to land is short, being in one place less than 25 miles. It will doubtless be some time before this portion of the work will be undertaken. The Morse instrument will be used.

Publications Issued.

BAROMETRICAL OBSERVATIONS IN THE ANTILLES AND NEIGHBOURING COUNTRIES. By M. C. Sainte Claire Deville. —A remarkable *brochure* on diurnal and annual variation, geographical differences, and the relations between atmospheric pressure and the synodic revolutions of the moon.

NOTES ON A LITTLE KNOWN FUNCTION OF THE PANCREAS—THE DIGESTION OF AZOTIZED FOOD. By M. Corvisart, Physician in Ordinary to the Emperor. Paris. —This work contains the results of the observations of many members of the French faculty, as well as of the author, and has attracted great attention.

Notes.

EXHIBITION OF DEAD POULTRY IN PARIS.—An exhibition of fat poultry is to take place next month, in the Palais de l'Industrie. Intending exhibitors are to apply, before the 1st of December, to the Minister of Commerce. On the first day of the exhibition, the jury will award the prizes in the morning, and the public will be admitted in the afternoon; on the second day, there will be a public exhibition, ending with a sale by auction.

FREE PUBLIC LABORATORY.—The French Government has decided on opening a free laboratory for practical chemistry, the direction being placed in the hands of M. Fremy, Member of the Institute, and Professor. M. Ménier, a manufacturing chemist, who proposed to open a similar establishment, has given up the idea in favour of the government plan, and has contributed the sum of 10,000 francs in aid.

THE TRAGOPAN.—Among the birds just received at the Jardin d'Acclimatation in the Bois de Boulogne, are some tragopans, a kind of Chinese pheasant, sent by M. Dabry, French consul at Han-Keou. These birds are called Too-chew-kee by the Chinese, a name meaning:—"The bird that vomits flakes of silk." They are brought from the mountains of Sze-Chwen, and also from the Hoopay, Fokin, and Kwang-Tong districts, where they are much esteemed by the inhabitants, both for their plumage and the delicacy of their flesh. Viceroys and rich people always keep some in cages as curiosities. The size of the tragopan does not exceed that of a common hen. Its plumage displays the most varied and brilliant colours. The head is jet-black with a gold-yellow crest; the eyes are large and bordered with blue; the neck is sky-blue, the breast a fiery red; the back and abdomen speckled white on a red ground. During summer it displays the magnificence of its plumage by puffing itself up and strutting about with the pride of a peacock, every now and then uttering a horse caw; then all at once it thrusts out a tongue at least a foot long, of a beautiful blue speckled with fiery spots along the middle, at the same time two charming little blue horns make their appearance on its head. This delightful spectacle lasts about a quarter of an hour, after which the bird withdraws its tongue, lets down its horns, and subsides again into its sober toilette for common wear, uttering an odd sound, as if in mockery of the spectators. This bird, according to Chinese naturalists, is not only one of the wonders of nature on account of its plumage, but it also possesses the most important virtue in the eyes of the Chinese, viz., filial piety, for the young ones take care of their parents when age or illness renders it impossible for them to provide for their own nourishment. This affectionate care has procured this creature the name of Hiao-Ky, or "bird of filial piety." It is also called Py Choo-Ky, or "bird that avoids trees," because it haunts rocks rather than woods. Its flesh is excellent, and the Chinese say it has the property of making a man intelligent. The tragopan is of the pheasant family, and this is the first time it has been seen in France. There is every reason to hope that it will be acclimatised.

Correspondence.

BROKERS AND MIDDLEMEN.—SIR,—Some remarks made by the Vice-Chancellor Sir W. Page Wood, in moving the well-earned thanks of the meeting of the 16th inst. to the Chairman of the Council, for his able address on the opening of the session, deserves, I think, some special notice, as putting in a clear and even a new point of view the real position and duties of the Society of Arts. He said that "this Society filled, with respect to Arts, Manufactures, and Commerce, the position which was occupied in commerce by the 'broker' or 'agent.'" We have so much to learn in this life that it is always desirable, and saves valuable time, if we can thus detect analogies between any two branches of knowledge, or any two systems of organisation which reflect light the one upon the other. This is especially the case if, as in this instance, one branch of the illustration is well known, and does not require to be argued at any length. Many persons then present practically knew the value of the broker, who "ascertained and supplied the wants and needs of different classes of the community." A trader has, perhaps unexpectedly, to buy a particular article. He is a stranger to the market, and goes, therefore, to the broker to purchase. Another trader has the same kind of article to sell, and, going to the same broker, he, the broker, then becoming a "middle man," is thus a convenience to both parties, and a benefit to the community. There is something analogous to this process in the retail shop; the analogy holds yet stronger in the wholesale warehouse, which assembles, under one roof, the productions of various and distant manufactories. So, a Society of Art, of Manufacture, or of Commerce, having relation at once with the inventor and the machine

maker—with the workmen and the employer of workmen—with the actual labourer and the capitalist—with art and the admirers of art—become "middle men" in the noble trade of science, and "brokers" in the exchange and the pursuit of knowledge. I could pursue the analogy further, but, if there be any truth in the analogy, your readers will better pursue it for themselves; and I can only add that, with a Prince for their President, and the heir to the throne in the chair, on the one hand, and their intimate and extensive connection with inventors, designers, manufacturers, and workmen of all classes and ranks on the other hand, it will go hard if they do not conduct their business, as a Society of Arts, Manufactures, and Commerce, with some degree of credit to themselves and with no small benefit to the community at large.—I am, &c., JOHN DILLON.

November 21, 1864.

MEETINGS FOR THE ENSUING WEEK.

MON. ...R. Geographical, 8½. 1. Viscount Milton and Dr. Cheadle, "Journey across the Rocky Mountains into British Columbia, by the Yellow Head Pass." 2. Mr. John Macdonald Stuart, "On his Last Journey of Exploration to Northern Australia, with an Account of the Country about to be Colonised on the Banks of the Adelaide River."
Actuaries, 7. Mr. W. M. Makeham, "Solutions of General Problems in Survivorships."

TUES. ...Civil Engineers, 8. Mr. E. H. Clark, "Description of the Great Grimsby (Royal) Docks, with a detailed account of the enclosed land, entrance locks, dock walls, &c."

WED. ...Society of Arts, 8. Mr. Bridges Adams, "On the Mechanical Conditions of Railway Working to Prevent Destructive Wear and Risk."
Royal, 4. Annual Meeting.

THURS...Antiquaries, 8.
Linnæan, 8. 1. Dr. Bastian, "On Nematode Worms." 2 Dr. Cobbold, "Brief Notice of Results obtained by Experiments with *Entozoa*." 3. Dr. Baird, "On Tubicolous Annelids, from the Collection in the British Museum."
Chemical, 8.

FRI.......Philological, 8.
Archæological Inst., 4.

SAT.......Artists and Amateurs, 7. Annual Meeting.

Patents.

From Commissioners of Patents Journal, November 18th.

GRANTS OF PROVISIONAL PROTECTION.

Aerated bread—2635—G. T. Bousfield.
Aeriform bodies, heating, cooling, &c.—2666—D. Laidlaw and J. Robertson.
Agricultural and traction engines, &c.—2662—J. Craven and S. Fox.
Animal charcoal, re-burning—2695—J. F. Brinjes.
Artificial stone—2664—E. J. W. Parnacott.
Axles—2698—W. E. Gedge.
Bolts or fastenings—2682—W. Clark.
Brackets—1975—E. and F. Crook.
Brushes—2671—J. and P. Goodall.
Buttons—2703—W. Aston.
Centrifugal pumps—2735—H. A. Gwynne.
Chimney pots for prevention of down draft—2775—J. Bell.
Cisterns, waste pipes of—2725—J. Cutler.
Clothing for horses, &c.—2705—R. Richardson.
Cotton-gins—2660—J. Shelmerdine.
Distilling—2749—F. H. Bickes.
Dyeing and printing, obtaining colouring matters for—2785—J. Dale, H. Caro, and C. A. Martins.
Electricity, application of as a motive power—2681—L. P. G. Bellet and C. M. P. De Rouvre.
Electric printing for telegraphic purposes—2687—J. H. Simpson.
Electric signals for gunnery practice—2423—F. N. Gisborne.
Fabrics and fibrous materials, drying, &c.—2685—J. L. Norton.
Filters—2757—J. Slack.
Fire-arms—2763—G. P. Harding and L. Thomas.
Fire-arms and projectiles—2669—J. P. Harriss.
Fire-arms, breech-loading—2741—J. Snider.
Fire-arms, breech-loading—2759—W. E. Newton and E. C. Shepard.
Fire-arms, breech-loading, and cartridges—2777—S. Rydbeck
Fire-places—2696—P. L. Charon.
Glue and size, manufacture of—2723—H. W. Spencer and J. E. Ball.
Grain, machinery for cleansing—2755—W. E. Gedge.
Gunpowder, manufacture of—2594—L. H. G. Ehrhardt.
Hydraulic engine and pump—2674—G. Rydill.
Hydrocarbons, distillation of matters capable of yielding—2673—W. Cormack.
Iron and steel, manufacture of—2738—F. Yates.
Jacquard apparatus for weaving figured fabrics—2743—D. Ellis and M. Hillas.
Kneading, measuring, and discharging dough—2694—E. Edwards.
Lace-making machinery—2676—J. Hartshorn and J. Gadsby.
Lamps for burning magnesium—2690—J. Solomon and A. G. Grant.
Lamps, preventing extinction of—2700—P. A. Roger.
Lighting rooms and buildings—2702—I. Schwartz.
Liquid manure, apparatus for distributing—2693—N. F. Andreasen.
Marking ink—2511—J. Moller.
Metallic articles, irregularly formed, machinery for shaping—2679—J. L. Davies.
Metallic substances, cutting and drilling—2715—C. W. Wardle and R. McIntyre.
Navigable vessels, constructing—2781—J. Robinson.
Omnibuses, tell-tales for—2721—W. Newbould.
Overground telegraph wires, insulating—2536—L. J. Crossley.
Panels, &c., constructing—2680—A. H. A. Durant & W. H. P. Gore.
Paper cloth—2311—L. Cooke.
Paper, manufacture of for preventing falsification of writings—2706—J. Forster and H. Draper.
Photographic process—2717—T. Fox.
Pianofortes, &c., stringing and tuning—2697—W. Moody.
Presses for expressing fluids—2692—J. M, Rowan.
Railway carriages, applying wheels and axles—2701—W. Rice.
Railway carriages, warming and cooling—2691—G. Davis.
Railway carriage signals—2670—W. Dowley.
Railways, rails for the permanent way of—2677—H. A. and J. E. Jowett, and J. B. Muschamp.
Railway trains, signalling between passengers and guards on—2712—F. J. Scott.
Railway wheels and axles, combining—2708—J. Furnevall and G. Keighley.
Railways, mechanism for preventing accidents on—2753—G. Simpson.
Resins and hydrocarbons, manufacturing and refining—2497—J. I. Vaughan.
Sea-water, conveying to inland places—2783—J. Rae.
Sewing machines, arrangement of for use in shoemaking—2667—W. Jackson.
Sextants, &c.—2665—R. A. Brooman.
Ships' sails, reefing—2570—J. Hart.
Shovels and spades, affixing the handle to—2449—J. O. Communay.
Spurs—2737—R. K. and K. T. Bowley.
Steam-engines—2699—T. Ivory.
Steam-engines—2711—J. Drury.
Steel, casting—2714—E. L. S. Benzon.
Sugar manufacture, centrifugal apparatus used in—2678—A. and W. Smith.
Syphons—2686—G. H. Devereux.
Syrups, manufacture of—2646—P. Dutrulle.
Textile fabrics, treatment of—2773—J. H. Johnson.
Utensils (chamber), fitting and mounting—2689—B. Scalé.
Vessels and ships, protecting the bottoms of—2672—G. Ager.
Whip-holder—1846—J. C. White.
Window-blinds, regulating cords of—2765—R. Montague.
Woven fabrics, lustreing and drying—2739—T. N. Kirkham, V. F. Enson, and H. Brook.
Yarns, apparatus for wringing, &c.—2661—J. Stobo and W. Pollock.
Yarns or fabrics, sizing, dressing, &c.—2668—J. and H. Charlton, and J. O. Christian.

INVENTION WITH COMPLETE SPECIFICATION FILED.

Carriages, opening and closing the heads of—2819—C. Martin.

PATENTS SEALED.

1235. L. L. Sovereign.	1313. H. M. Harwood and G. Whitford.
1281. J. Edwards.	1386. W. Clark.
1284. W. G. Todman and J. H. Todman.	1714. J. W. Horsfall.
1285. C. P. Coles.	1842. D. Barker.
1296. B. Jones.	2118. J. Campbell.
1297. G. Moulton.	2222. J. Williams.
	2223. H. C. Baildon.

From Commissioners of Patents Journal, November 22nd.

PATENTS SEALED.

1306. G. Davies.	1399. J. Dodge.
1307. H. Redfern.	1427. J. T. Crick.
1310. J. H. Brown.	1569. J. Holt.
1311. C. Boutet.	1612. W. Clark.
1322. J. Hudson and C. Catlow.	1636. M. P. W. Boulton.
1341. G. Herbert & R. Stainbank.	1923. A. Smith.
1346. G. Davies.	2008. G. Haseltine.
1362. F. O. Ward.	2126. J. Lones.
1375. F. O. Ward.	2193. J. Fleming.
1377. J. J. McComb.	2254. A. Bertsch.
1380. F. Ashe.	2361. J. Mackay.

PATENTS ON WHICH THE STAMP DUTY OF £50 HAS BEEN PAID.

2914. F. Johnson.	2915. J. C. Croxford.
2896. R. A. Brooman.	2919. E. Peyton and W. F. Batho.
2903. T. Redwood.	

PATENTS ON WHICH THE STAMP DUTY OF £100 HAS BEEN PAID.

2864. G. P. Wheeler.	2968. F. G. Grice.
950. W. Blinkhorn.	2927. J. M. A. E. Fabart.